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EFFECTS OF HIGH-FIDELITY SIMULATION ON NURSING STUDENTS' LEARNING OUTCOMES IN CRITICAL CARE: A SYSTEMATIC REVIEW AND META-ANALYSIS

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Title:

Effects of high-fidelity simulation on nursing students' learning outcomes in critical care: a systematic review and meta-analysis

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ABSTRACT

Objective. The purpose of this systematic review was to analyse the effectiveness of high-fidelity patient simulation (HFPS) utilizing critical care scenarios on nursing students' learning outcomes.

Design. A systematic review and meta-analysis were conducted based on the Cochrane Handbook for Systematic Reviews of Interventions and its reporting was checked against the PRISMA checklist.

Data sources. PubMed, Scopus, CINAHL with Full Text, Wiley Online Library, and Web of Science were searched through July 2017. Author contact, reference, and citation lists were checked to obtain additional references.

Study selection. To be included in the systematic review, available full-texts had to be published in English, French, Spanish or Italian and: (a) described high-fidelity simulation based on critical care scenarios; (b) contained control groups not tested on the HFPS before the intervention; (c) contained data measuring learning outcomes such as performance, knowledge, self-confidence, self-efficacy or satisfaction measured just after the simulation session; and (d) reported data for meta-analytic synthesis.

Review method. Three independent raters screened the retrieved studies using a coding protocol to extract data in accordance with inclusion criteria.

Synthesis method. For each study, outcome data were synthesized using meta-analytic procedures based on random-effect model and computing effect sizes by Cohen's *d* with a 95% confidence interval.

Results. Thirty-three studies were included. HFPS sessions showed significantly higher effects sizes for knowledge ($d = 0.49$, 95% CI [0.17; 0.81]) and performance ($d = 0.50$, 95% CI [0.19; 0.81]) when compared with any other teaching method.

Limitations. Only a few studies had a high-quality design, therefore generalizability of results is limited.

Conclusions. HFPS revealed higher effects sizes on nursing students' knowledge and performance when compared to other teaching methods. However, further studies are required to explore its effectiveness in improving nursing students' competence and patient outcomes.

Strengths and limitations of this study

- This meta-analysis is the first to provide data on the impact of high-fidelity patient simulation sessions based on critical care scenarios on several learning outcomes (i.e. knowledge, performance, satisfaction, self-confidence, and self-efficacy) in a population of academic nursing students.
- The utilization of a robust, structured search strategy across multiple databases allowed for the identification of 33 studies published from 2006 to 2017 that reported the impact of critical care high-fidelity patient simulation on nursing students' learning outcomes.

- Data heterogeneity and the limited availability of high-level evidence limits the generalizability of results in current nursing education practice.

INTRODUCTION

Health care systems and health needs of general population worldwide require newly registered nurses to have adequate knowledge, skills, and attitudes in order to be 'fit for practice'.[1 2] The clinical training of nursing students plays an essential role in the learning process during undergraduate courses,[3] but the unpredictable nature of the clinical training environment can generate risk of error potentially harmful for both nursing students [4 5] and patients.[6 7] Since available evidence assume that the safety for both patients and learners rises together with the growth of students' clinical expertise,[4 8] an active learning method may allow nursing students to practice clinical procedures learned in theory and patients to receive best-quality safe care .[9 10] Unfortunately, the organizational issues and short rotations in clinical settings do not always allow nursing students to train in an interactive way especially in high-risk, low incidence clinical events.[11] All these reasons have generated the need for integrative teaching methods, such as high-fidelity patient simulation (HFPS). The HFPS utilizes technologically improved manikins that are able to breathe, talk, and have both heart and lung sounds, programmed by algorithms or dynamic 'off-the-cuff' instructions to replicate the physiological parameters in normal or deteriorating patients.[12] This method allows for giving and receiving feedback on repeated actions permitting the shift from theory to lived experience for the student within a safe learning environment rich with opportunities.[13 14] The use of high-fidelity patient simulators has been shown to improve nursing students' learning outcomes, such as satisfaction, self-confidence, and self-efficacy,[15] as well as knowledge and performance [16 17] by means of deliberate practices, feedback opportunities, and gradually augmented task difficulties.[18] Moreover, the usefulness of the forgiving nature of the simulation environment is often acknowledged and appreciated by students who experience HFS sessions.[15] Consequently, HFPS has become an important learning strategy in nursing education [3 6 19 20] since it provides the opportunity to frequently experience acute clinical situations without risk to the patient or learner.[19 21 22].

Although primary studies widely document the potential of HFPS to improve nursing students' learning outcomes, [17 23] literature does not offer a wide overview of the effectiveness of the simulation when performed through critical care-based scenarios requiring rapid and effective interventions. Therefore, considering the increase of published studies on the effectiveness of HFPS in academic nursing education, a systematic analysis of these studies is expected to allow the development of guidelines in this field.

Objectives

The aim of this systematic review was to analyse the effectiveness of HFPS critical care scenarios in improving the learning outcomes of knowledge, self-confidence, satisfaction, self-efficacy, and performance for undergraduate and post-graduate nursing students.

METHODS

A systematic review and meta-analysis were conducted based on the Cochrane Handbook for Systematic Reviews of Interventions [24] and its reporting was checked against the PRISMA checklist.[25]

Eligibility and inclusion criteria

In order to be included in this analysis, the abstract had to clearly indicate the study: (a) was experimental or quasi-experimental; (b) had utilized HFPS and (c) had involved nursing students (undergraduate or postgraduate). Available full-texts had to be published in English, French, Spanish or Italian language and studies had to include: (a) HFPS based on critical care scenarios; (b) control groups not tested on the HFPS before the intervention; (c) data on the learning outcomes of performance, knowledge, self-confidence, self-efficacy or satisfaction measured just after the simulation session; and (d) data for meta-analytic synthesis. For the purpose of this systematic review, the concept of knowledge was intended as deliver of the theoretical basis of caring,[26] self-confidence is defined as trusting the soundness of one's own judgment and performance,[22] satisfaction is considered the fulfilment of student's expectations during the simulation experience,[27] self-efficacy consists of the way students perceive, think, and motivate themselves when learning and performing clinical training,[28] and, finally, performance is referred to the demonstration of clinical skills.[29]

Information sources and search

A pilot search was performed to identify keywords and MeSH headings relevant for the electronic research. PubMed, Scopus, CINAHL with Full Text, Wiley Online Library, and Web of Science were searched until July 2017 using the search strategies listed in the supplementary file. To perform an exhaustive search, reference and citation lists from included studies were checked for other relevant references. Thomson Reuters EndNote® X7 was used for the management of the retrieved studies and references.

Study selection

Titles and abstracts of the searched studies were screened by three raters (CLC, AD, and VC) and, for each eligible study, full-texts were retrieved by using online databases and faculty interlibrary service, as well as by contacting authors. The consistency of raters' judgments was checked estimating the Krippendorff's alpha coefficient (α).[30] Any disagreement between the raters was resolved by discussion until consensus was reached.

Data collection process

For the purposes of this systematic review, a coding protocol was designed by the research team and developed with a spread sheet built with Microsoft Excel. To obtain an accurate version of the tool, the form was tested independently by two authors (CLC and AD).

Data items and quality appraisal of individual studies

Data related to year of publication, journal, study design, country, sample size, participants characteristics, simulator features, control interventions, scenarios, outcomes and measurement tools, and time of exposure to scenarios were extracted independently by two authors (AD and CLC). Krippendorff's alpha was used to calculate inter-rater reliability and any disagreement about data extraction was resolved by discussing with a third author (LL) to gain consensus.[30] The study designs were checked with 'List of study design features'.[24]

The included studies were screened for their methodological quality through the Quality Appraisal Checklist for Quantitative Intervention Studies designed by the National Institute for Health and Care Excellence (NICE).[31] To provide a global measure for both external and internal validity, the most frequent judgment was utilized.

Synthesis of results and summary measures

For each study, the outcome data were synthesized through meta-analytic procedures using the software ProMeta 3.0. The random-effect model was used for all studies as a conservative approach to account for different sources of variation among studies (between-studies and within-study variance).[32 33] Starting with original data, Cohen's *d* (standardized mean difference) was directly computed or derived.[34] Effect sizes were pooled across studies to obtain an overall effect size with the inverse-variance method. For each effect size, the corresponding 95% confidence interval (CI), weight, and statistical significance were calculated. The historical trends from the databases analyzed were graphed.

Risk of bias across studies and additional analyses

Publication bias was examined by the funnel plot,[35] Egger's regression,[36] Trim and Fill, and the Fail-safe number methods were utilized to assess the effect of publication bias on effect size.[35] Since robust eligibility criteria were adopted and the reliability of data extraction was guaranteed by a multi-rater approach, data were presented considering any acceptable level of heterogeneity which was checked and measured with Q-test and I^2 and explored through sub-group analyses,[37] utilizing the 'scenario', 'manikin brand', 'control intervention', and 'randomization' as moderators. ProMeta 3.0 and IBM SPSS version 19.0 (IBM Corp., Armonk, New York, USA) were utilized for data analysis while GNU Octave 4.2.1 was utilized for plotting meta-analysis.

Patient and public involvement

This was a review without contact to patients. All information was obtained from published studies.

RESULTS

Study selection

The search produced 2603 references from databases and 1857 studies from reference and citation searching. A significant increase in the general number of studies ($R^2 = 0.835$; $p < 0.001$) over the last 30 years about HFPS was detected (Figure 1).

After removing duplicates, 2130 abstracts were screened for relevance. Consequently, 492 full-texts were analyzed and 459 studies were excluded for not meeting the inclusion criteria (Figure 2). Inter-

rater reliability for abstracts and full-texts was $\alpha = 0.84$ and $\alpha = 1.00$, respectively, before consensus among authors was reached. The final sample of 33 studies originating 44 comparisons was included in this systematic review, as shown in the supplementary file.

Study characteristics

Detailed information about study characteristics are presented in the supplementary file. Summaries about more significant features of included studies are presented as follows:

Sample participants

The overall sample of nursing students (n = 3042) showed sample sizes varying from 17 to 352 participants composed of undergraduate (85.71%) and post-graduate students (14.29%) and had a mean age of 25.72 (SD 5.75). Just over half of the studies (57.57%) were conducted in North America (USA 45.45% and Canada 12.12%), about 9.00% in Europe (United Kingdom 6.06% and Portugal 3.03%), 15.15% were conducted in South Korea, 9.09% in Jordan, while 9.09% in other countries (Australia, Singapore, and Turkey). Students in their fourth year of undergraduate courses (30.30%) were represented in ten studies conducted in Canada, Portugal, United States of America, South Korea, and Jordan. Most studies did not provide descriptive statistics related to gender.

Interventions and comparisons

Studies utilized a variety of both HFPS (intervention group) and other teaching methods (control group). Most of scenarios were typically run by qualified instructors or tutors and utilized Laerdal SimMan® in the intervention groups (47.00%). Simulation sessions were based mainly on cardio-circulatory scenarios (30.91%), followed by respiratory scenarios (49.09%) and others (20.00%). For the control group interventions, more than one third utilized lectures (31.00%), no intervention (24.00%), or low-fidelity manikin (11.00%).

Outcome measures

All outcomes in the included studies were based on self-reported instruments and through direct observation of performance by raters. Different types of measurement tools were detected including Likert-type scales (43.86%), multiple-choice questionnaires (19.30%), dichotomous scales (12.28%), checklists (5.26%), open questions (1.75%), and others (17.55%).

Type of studies

Most studies included in this meta-analysis were based on a quasi-experimental design with a pseudo-randomized allocation to groups (87.88%) while the remaining studies (12.12%) were randomized controlled trials. The included studies were published from 2006 to 2017 and their design features are available for consultation in the supplementary file.

Quality appraisal of individual studies

Good internal validity was reported for all included studies (supplementary file), while 42.42% of the studies demonstrated good external validity, and just over half depicted a scarce generalizability of the results mainly due to lack of details concerning the process of recruiting participants (57.58%).

Results of individual studies and synthesis of results

HFPS sessions showed significant higher effects sizes for knowledge (d = 0.49, 95% CI [0.17; 0.81]) and performance (d = 0.50, 95% CI [0.19; 0.81]) than any other teaching method (Figure 3). No significant differences were detected between HFPS and control groups for the subjective outcomes of satisfaction, self-confidence, and self-efficacy.

Since Q-test highlighted a significant heterogeneity for all the outcomes (Figure 3), subgroup analyses were carried out to determine its source (Table 1). The scenario topic, type of manikin, control group treatment, and method of selecting groups appeared to be the source of heterogeneity for self-efficacy. Otherwise, these moderators did not prove to be the sources of heterogeneity for the remaining learning outcomes.

Table 1. Nursing students' learning outcomes subgroup analyses

Moderators	Categories	Knowledge Q=79.16 I^2=84.84% $p\leq0.01$			Performance Q=122.54 I^2=83.68% $p\leq0.01$			Satisfaction Q=118.24 I^2=89.85% $p\leq0.01$			Self-confidence Q=76.58 I^2=79.11% $p\leq0.01$			Self-efficacy Q=13.37 I^2=70.09% $p\leq0.01$		
		Q	I^2	Sig.	Q	I^2	Sig.	Q	I^2	Sig.	Q	I^2	Sig.	Q	I^2	Sig.
Scenario	Cardio-circulatory	63.38	90.53	**<0.001**	82.99	85.54	**<0.001**	6.67	40.07	0.154	18.87	73.51	**0.002**	0.83	0.00	0.362
	Respiratory	8.81	65.95	**<0.001**	19.65	79.65	**0.001**	111.41	93.72	**<0.001**	29.23	79.47	**<0.001**	1.12	10.47	0.291
	Other	2.76	63.76	0.097	10.18	80.35	**<0.001**	-	-	-	28.33	85.88	**<0.001**	-	-	-
Manikin	METI™	30.02	93.34	**<0.001**	48.13	87.53	**<0.001**	-	-	-	24.22	87.61	**<0.001**			
	Laerdal®	3.47	0.00	0.482	59.94	86.65	**<0.001**	24.49	83.67	**<0.001**	5.43	26.38	0.246	0.83	0.00	0.362
	Unspecified	22.97	82.58	**<0.001**	3.63	0.00	0.458	89.84	93.32	**<0.001**	47.47	83.15	**<0.001**	1.95	0.00	0.377
	Med Sim Eagle	-	-	-	-	-	-	na	na	na	-	-	-	-	-	-
Controls	Low-fidelity manikin	16.42	87.82	**<0.001**	4.74	57.82	0.093	-	-	-	na	na	na	-	-	-
	Lecture	53.54	94.40	**<0.001**	20.00	85.00	**<0.001**	15.32	73.89	**0.004**	23.83	74.82	**0.001**	na	na	na
	Medium-fidelity manikin	Na	na	na	-	-	-	3.94	49.19	0.140	0.40	0.00	0.528	na	na	na
	No intervention	0.36	0.00	0.548	48.75	87.69	**<0.001**	-	-	-	8.14	63.16	**0.043**	na	na	na
	Problem-based learning	Na	na	na	3.39	70.47	0.066	na	na	na	na	na	na	-	-	-
	Web-based learning	Na	na	na	-	-	-	2.15	53.46	0.143	-	-	-	-	-	-
	Standardized patient	Na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Role-playing	-	-	-	na	na	na	na	na	na	na	na	na	na	na	na
	Video-watching	-	-	-	na	na	na	-	-	-	-	-	-	-	-	-
	Audio-listening	-	-	-	1.72	41.96	0.189	-	-	-	na	na	na	-	-	-

Note: not applicable for number of studies = 1 (na); no studies (-)

Risk of bias

With the exception of self-efficacy, no significant publication biases were detected on performed tests measuring knowledge, performance, satisfaction, and self-confidence.

DISCUSSION

Study characteristics

In this review, a significant increase in HFPS research based on critical care scenarios was detected over the years, which recognizes simulation-based education as a key component of nursing education [38 39] especially for critical care clinical conditions requiring rapid and effective interventions. Although a positive publication trend on this topic emerged, most of the research had been conducted in North America. Consequently, generalizability of results in Europe and Asia is limited given the differences in many academic and curriculum aspects.[40]

In accordance with global health concerns,[41-43] critical care scenarios utilized in HFPS sessions were mainly based on cardio-circulatory and respiratory clinical conditions that allowed students to manage high risk, low incidence critical situations.[11] In order to comprehend if patients will receive

better and secure care, translational research on HFPS should be strengthened. Moreover, given the variety of measurement tools (e.g. Likert-type, multiple choice, etc.), research methods on this topic should be more focused and rigorous. *Ad hoc* scenario-specific instruments with reported reliability and validity should meet the minimum general requirements of global shared guidelines in order to have comparable results. Standardization of their core contents is strongly advisable. This meta-analysis should be read considering that few included studies had a good external validity and adopted a randomized controlled design. Moreover, conducting high-quality replication studies on this topic utilizing common measurement instruments is recommended.[19 44]

HFPS and nursing students' learning outcomes

This systematic review was the first to analyze the effectiveness of HFPS utilizing critical care scenarios on nursing students' learning outcomes. In accordance with other reviews conducted on this topic,[17 23] although with different aims and populations, HFPS seems to improve students' knowledge [18 32 34 37 45-52] and performance [32 48 53-64] when compared with other teaching methods.

Considering that competence can be defined as knowledge and performance combined with psychomotor and clinical problem-solving skills,[65] HFPS can be considered an important teaching method that can contribute to build nursing competence especially in the area of critical care. Engaging in simulated critical care scenarios, students can improve their ability to provide appropriate and safe nursing care in patients' with unstable and rapidly changing clinical conditions. However, it is not enough for nursing students to just demonstrate good knowledge and performance to completely achieve their learning outcomes as well as securely meet the needs of the critically ill patient. Considering that nursing is an aid profession and that patients need to feel safe and reassured, adequate levels of self-confidence and self-efficacy [66] are required in order to improve the well-being of nurses that is closely linked to the quality of care provided. However, this review does not confirm the benefits of HFPS based on critical care scenarios in improving nursing students' self-efficacy [62 63 67 68], self-confidence [46 47 49 52 53 56 62 63 67 69-74], and satisfaction [45-47 62 71 73 75-78]. Probably, non-significant results for these learning outcomes are due to measurement immediately after any single simulation experience, not allowing the detection of any change. To achieve significant improvements in self-efficacy and self-confidence, it may be useful to provide students with repeated exposures to the HFPS sessions in order to maintain successful performances over time and allow them to observe the success of the other students to increase encouragement and engagement.[66 79 80] Hence, future studies should utilize repeated exposures to the HFPS with outcome evaluation during both intermediate- and long-term intervals. The increased use of HFPS in nursing education programs may result in more clinically confident and proficient nurses who are able to respond accurately and appropriately to patients' needs [81]. To better understand how the gain in performance and knowledge improves patient outcomes, more research based on translational approach is required.[44]

The results from this meta-analysis are affected by a high heterogeneity and was not explained by those variables except for self-efficacy, and was likely due to the different application methods of HFPS across several context of the studies. Unfortunately, most studies did not provide data useful to exploring the reasons for the heterogeneity that represents both a threat to the reliability of the results [82] and an opportunity to provide a quantitative proof of the methodological limitations in the current research.

The unexplained heterogeneity detected from this meta-analysis have a surprising usefulness in orienting future research to provide evidence-based responses to various unsolved questions related to the ability of HFPS to improve nursing learning outcomes. Further details are needed in regards to how long should a simulation session last? What are the best briefing and debriefing methods? What are the most effective facilitation methods to use during the simulation? What is the ideal number of participants in each session? Studies that answer these questions through shared investigation methods would allow to establishment of guidelines, protocols, and algorithms [83 84] that interrupt the vicious circle in which the lack of homogeneity in the behaviors determines a heterogeneity of the results and vice versa.

Limitations

This systematic review is the first available in literature to analyze the effectiveness of HFPS through critical care scenarios on nursing students learning outcomes; however, some limitations were revealed. Although good internal validity was reported for all the included studies, only a few had a high-quality design that, together with the relevant heterogeneity, invites to cautiously generalize the results.

Since publication bias for self-efficacy was detected, further studies measuring self-efficacy as a learning outcome are necessary. Finally, lack of data about the participants' characteristics, measurement tools, duration of the session, and briefing and debriefing modalities limit the analyses and interpretation of the results.

Conclusions

Results of this systematic review demonstrate HFPS is superior to other teaching methods in improving knowledge and performance of nursing students when exposed to critical care scenarios, corroborating the importance of HFPS into the academic educational programs especially for the management of clinically acute events. Students trained by HFPS acquire more awareness when performing procedures at the patients' bedside and show positive behavioral modifications that may provide better patients' outcomes. However, more studies are still necessary to explore the potential use of the HFPS as an effective tool to increase nursing students' competence levels and to better understand its impact on patient outcomes.

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Competing interests

None declared.

Contributors

All authors developed the protocol, interpreted the results, and approved the final version. CLC, AD, IF, EG and VC completed the search, screened articles for inclusion, and synthesised the findings. CLC and AD extracted data. CLC and AD drafted the manuscript. CP, CA and LL critically revised the manuscript.

Patient consent

Not required.

Data sharing statement

There are no unpublished data for this review.

Figure 1. HFPS publication trend

Figure 2. Search and selection strategy PRISMA flow-chart

Figure 3. Effect of HFPS on nursing students' learning outcomes

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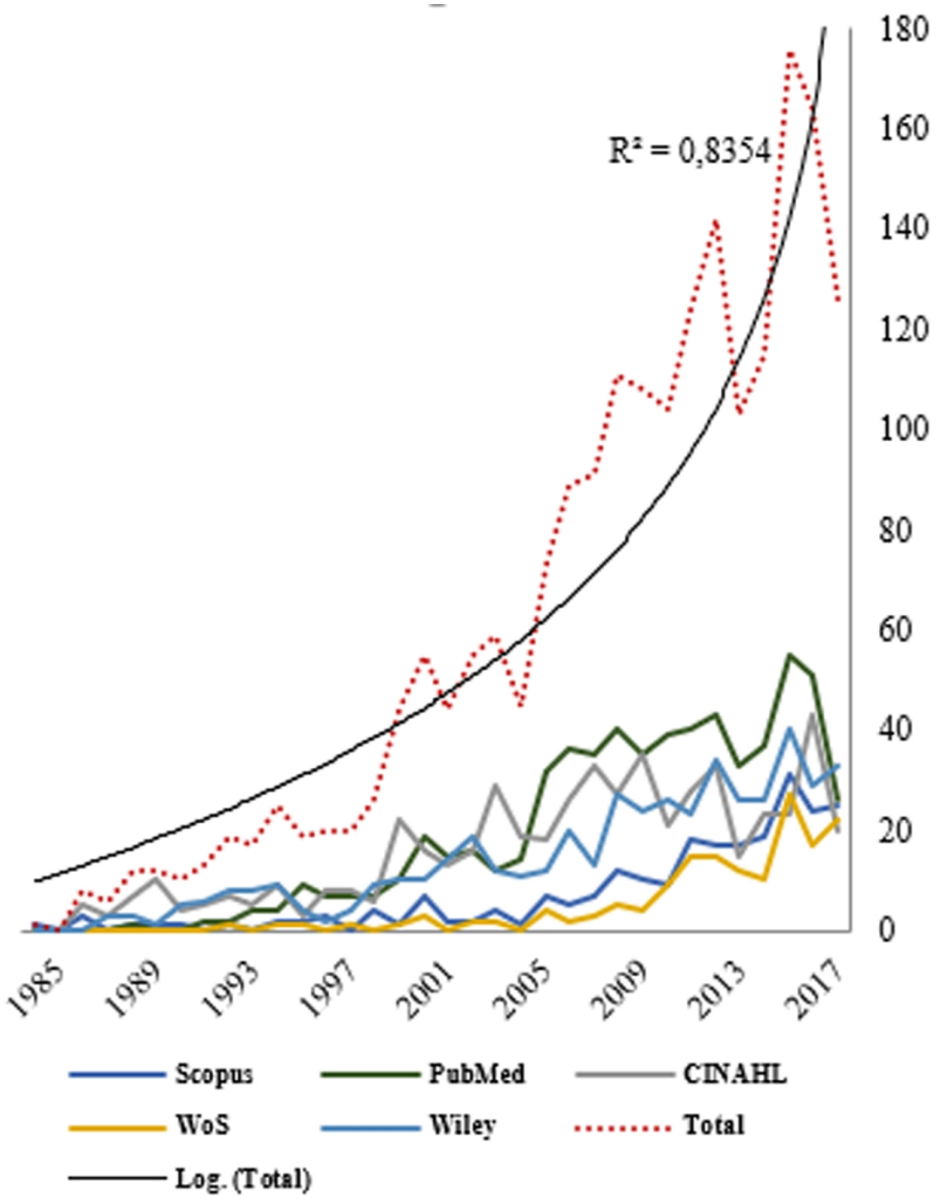

Figure 1. HFPS publication trend

124x149mm (300 x 300 DPI)

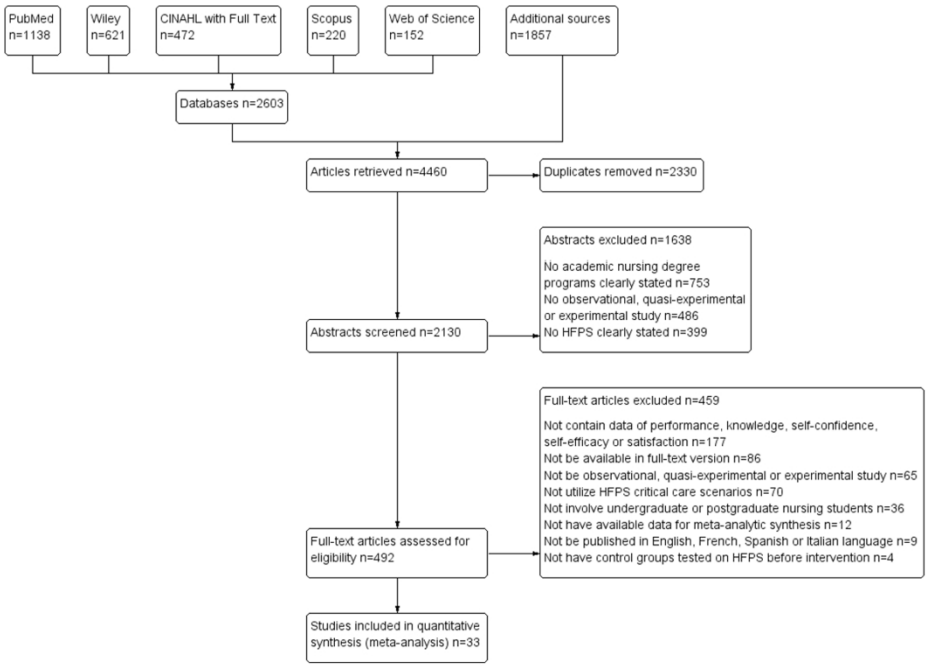

Figure 2. Search and selection strategy PRISMA flow-chart

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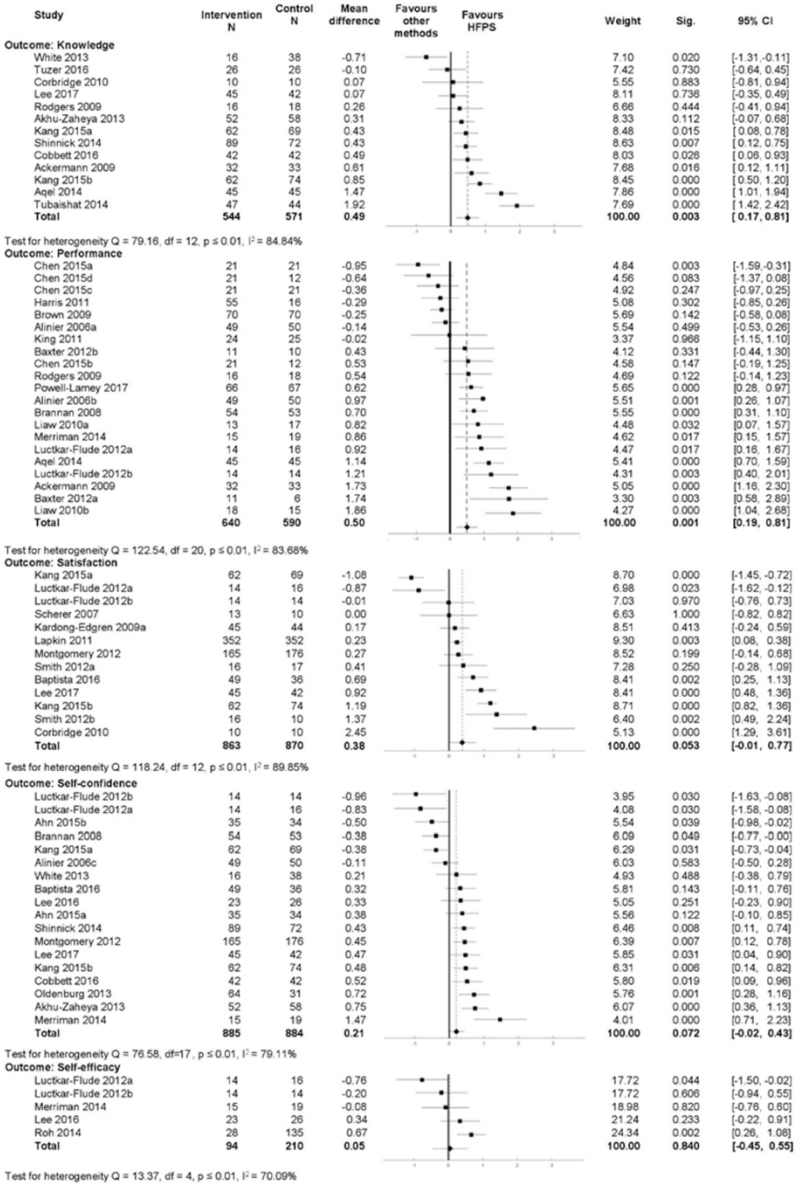

Figure 3. Effect of HFPS on nursing students' learning outcomes

466x613mm (300 x 300 DPI)

Supplementary file

Complete search strategy

PubMed

1. exp Education, nursing/
2. nurs$.ti,ab.
3. educat$.ti,ab.
4. 2 and 3
5. “nursing degree course”.ti,ab.
6. student$.ti,ab.
7. 2 and 6
8. exp Students, nursing/
9. "teaching and learning model".ti,ab.
10. 2 and 9
11. exp Teaching/
12. 2 and 11
13. 1 or 4 or 5 or 7 or 8 or 10 or 12
14. "acute care".ti,ab.
15. AED.ti,ab.
16. exp Airway management/
17. exp Cardiovascular diseases/
18. CPR.ti,ab.
19. exp Critical care/
20. exp Critical care nursing/
21. exp Life support care/
22. defibrillat$.ti,ab.
23. exp Defibrillators/
24. exp Electrocardiography/
25. ECG.ti,ab.
26. exp Electric countershock/
27. electrocardio$.ti,ab.
28. exp Emergencies/
29. exp Emergencies nursing/
30. exp Emergency medical service/
31. exp Emergency treatment/
32. exp Hemodynamics/
33. exp Monitoring, physiologic/
34. "patient deterioration”.ti,ab.
35. exp Respiration disorders/
36. exp Respiration, therapy/
37. 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36
38. fidelity.ti,ab.
39. “human patient”.ti,ab.
40. mannequin$.ti,ab.
41. exp Program development/
42. scenario$.ti,ab.
43. “simulated patient$”.ti,ab.
44. “simulation-based training".ti,ab.
45. 38 or 39 or 40 or 41 or 42 or 43 or 44
46. exp Mental processes/
47. $confiden$.ti,ab.
48. exp Clinical decision-making/
49. debrief$.ti,ab.
50. exp Educational measurement/
51. "fitness to practice".ti,ab.
52. gain$.ti,ab.
53. exp Health knowledge, attitudes, practice/
54. exp Needs assessment/
55. "objective structured clinical examination".ti,ab.
56. OSCE.ti,ab.
57. perceive$.ti,ab.
58. perception$.ti,ab.
59. performance$.ti,ab.
60. exp Personal satisfaction/

61. "physical assessment".ti,ab.
62. exp Psychomotor performance/
63. exp Aptitude tests/
64. retention$.ti,ab.
65. retain$.ti,ab.
66. satisfact$.ti,ab.
67. exp Self concept/
68. aware$.ti,ab.
69. efficac$.ti,ab.
70. skill$.ti,ab.
71. 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70
72. 13 and 37 and 45 and 71
73. limit 72 to (article type="Comparative Study", "Journal Article", "Observational Study". "Clinical Trial", "Controlled Clinical Trial", "Randomized Trial") and (publication date to "2017/05/31")

Scopus

TITLE-ABS-KEY (((nurs* AND educat*) OR "nursing degree course" OR (nurs* AND student*) OR ("teaching and learning model" AND nurs*)) AND ("acute care" OR aed OR cpr OR defibrillat* OR ecg OR electrocardio* OR "patient deterioration") AND (simulat* OR fidelity OR "human patient" OR manikin* OR mannequin* OR scenario*) AND (*confiden* OR debrief* OR "fitness to practice" OR gain* OR "objective structured clinical examination" OR osce OR perceive* OR perception* OR performance* OR "physical assessment" OR retention* OR retain* OR satisfact* OR aware* OR efficac* OR skill*)) [Article types: Article, Article in Press]

CINAHL with Full Text

S71 limit S70 to (document type="academic publication", "journals", "CEU"), ("research article"), (year="1900.01.01"-"2017.05.31") and expand to ("search also in full text")
S70 S12 and S35 and S43 and S69
S69 or/S44-S68
S68 (MH “Mental Processes”)
S67 AB (skill*)
S66 AB (efficac*)
S65 AB (aware*)
S64 (MH "Self Concept+")
S63 AB (satisfact*)
S62 AB (retain*)
S61 AB (retention*)
S60 (MH “Aptitude Tests”)
S59 (MH "Psychomotor Performance+")
S58 AB ("physical assessment")
S57 (MH "Student Satisfaction+")
S56 AB (performance*)
S55 AB (perception*)
S54 AB (perceive*)
S53 (MH "Student Performance Appraisal+")
S52 AB (OSCE)
S51 AB ("objective structured clinical examination")
S50 (MH "Needs Assessment")
S49 (MH "Health Knowledge")
S48 AB (gain*)
S47 AB ("fitness to practice")
S46 (MH "Educational Measurement+")
S45 AB (debrief*)
S44 AB (*confiden*)
S43 or/S36-S42
S42 (MH "Program Development+")
S41 (MH "Problem-Based Learning")
S40 AB (mannequin*)
S39 AB (manikin*)
S38 (MH "Learning Environment+")
S37 AB ("human patient")
S36 AB (fidelity)
S35 or/S13-S34
S34 (MH "Respiration Therapy+")
S33 (MH "Respiration Disorders+")

S32 AB ("patient deterioration")
S31 (MH "Monitoring, Physiologic+")
S30 (MH "Hemodynamics+")
S29 AB (electrocardio*)
S28 AB (ECG)
S27 (MH "Defibrillation")
S26 (MH "Defibrillators+")
S25 AB (defibrillat*)
S24 (MH "Life Support Care+")
S23 (MH "Critical Care Nursing+")
S22 (MH "Emergency Treatment+")
S21 (MH "Emergency Medical Service+")
S20 (MH "Emergency Care+")
S19 (MH "Emergencies+")
S18 (MH "Critical Care+")
S17 AB (CPR)
S16 (MH "Cardiovascular Diseases+")
S15 (MH "Airway Management+")
S14 AB (AED)
S13 AB ("acute care")
S12 or/S1-S8 or S11
S11 S9 and S10
S10 AB (nurs*)
S9 (MH "Teaching+")
S8 AB ("teaching and learning model" and nurs*)
S7 (MH "Students, Nursing+")
S6 AB (nurs* and student*)
S5 AB ("nursing degree course")
S4 AB (nurs* and educat*)
S3 (MH "Emergency Nursing+")
S2 (MH "Education, Nursing+")
S1 (MH "Education, Competency-Based+")

Wiley Online Library
(nurs* AND educat*) OR "nurse faculty" OR "nursing degree course" OR (nurs* AND student") OR ("teaching and learning model" AND nurs*) in Abstract AND ("acute care" OR AED OR CPR OR defibrillat* OR ECG OR electrocardio* OR "patient deterioration") in FullText AND (simulat* OR fidelity OR "human patient" OR manikin* OR mannequin* OR scenario*) in Abstract AND (*confiden* OR debrief* OR "fitness to practice" OR gain* OR "objective structured clinical examination" OR OSCE OR perceive* OR perception* OR performance* OR "physical assessment" OR retention* OR retain* OR satisfact* OR aware* OR efficac* OR skill*) in FullText [Publication Type: Journals]

Web of Science
TS=(((nurs* AND educat*) OR "nursing degree course" OR (nurs* AND student*) OR ("teaching and learning model" AND nurs*)) AND ("acute care" OR AED OR CPR OR defibrillat* OR ECG OR electrocardio* OR "patient deterioration") AND (simulat* OR fidelity OR "human patient" OR manikin* OR mannequin* OR scenario*) AND (*confiden* OR debrief* OR "fitness to practice" OR gain* OR "objective structured clinical examination" OR OSCE OR perceive* OR perception* OR performance* OR "physical assessment" OR retention* OR retain* OR satisfact* OR aware* OR efficac* OR skill*)) [All years, Document Types: Article]

Description of included studies (n = 33; k = 44)

1	1	Ackermann 2009	Investigation of learning outcomes for the acquisition and retention of CPR knowledge and skills learned with the use of high-fidelity simulation	Clinical Simulation in Nursing	1.277	USA	To investigate the impact of variables such as accelerated versus traditional nursing students and the experience with CPR on a living person.	Undergraduate (Baccalaureate)	65	1st	nd	nd
2a **2b**	2 3	Ahn 2015	Implementation and outcome evaluation of high-fidelity simulation scenarios to integrate cognitive and psychomotor skills for Korean nursing students.	Nurse Education Today	2.533	South Korea	To implement two high-fidelity simulations to help nursing students integrate their cognitive and psychomotor skills.	Undergraduate (Bachelor)	69	3rd	IG 20.13 (1.24) CG 20.81 (2.65)	IG 32 (91.4) CG 32 (94.1) All 64 (92.75)
3	4	Akhu-Zaheya 2013	Effectiveness of simulation on knowledge acquisition, knowledge retention, and self-efficacy of nursing students in Jordan	Clinical Simulation in Nursing	1.277	Jordan	To examine the effect of high-fidelity BLS simulation on knowledge acquisition, knowledge retention, and self-efficacy of Jordanian nursing students	Undergraduate (Bachelor)	110	2nd	20.00 (0.60)	74 (67.00)
4a **4b** **4c**	5 6 7	Alinier 2006	Effectiveness of intermediate□fidelity simulation training technology in undergraduate nursing education.	Journal of Advanced Nursing	1.998	UK	To determine the effect of scenario-based simulation training on nursing students' clinical skills and competence.	Postgraduate (Diploma)	99	2nd	IG 29.30 (7.5) CG 33.00 (8.40) All 31.20 (8.20)	IG 42 (85.70) CG 41 (82.00) All 83 (83.84)
5	8	Aqel 2014	High□Fidelity Simulation Effects on CPR Knowledge, Skills, Acquisition, and Retention in Nursing Students.	Worldviews on Evidence□Based Nursing	2.103	Jordan	To examine the effect of using high-fidelity simulators on knowledge and skills acquisition and retention with university students.	Undergraduate (Baccalaureate)	90	2nd	19.87 (1.78)	71 (78.90)
6	9	Baptista 2016	Satisfaction and gains perceived by nursing students with medium and high-fidelity simulation: A randomized controlled trial.	Nurse Education Today	2.533	Portugal	To analyze and benchmark gains and satisfaction perceived by nursing students, according to their participation in medium- and high-fidelity simulated practice.	Undergraduate (Bachelor)	85	4th	21.89 (2.81)	IG 44 (49.80) CG 35 (97.22) All 79 (92.94)
7a **7b**	10 11	Baxter 2012	Teaching Critical Management Skills to Senior Nursing Students: Videotaped or Interactive Hands□On Instruction?	Nursing Education Perspectives	0.91	Canada	To examine and compare the effectiveness of videotape training versus hands-on instruction in preparing senior nursing students to respond to emergency clinical situations.	Undergraduate (Bachelor)	17 (a) 21 (b)	4th	nd	nd
8	12	Brannan 2008	Simulator effects on cognitive skills and confidence levels.	Journal of Nursing Education	1.28	USA	To compare the effects of two instructional methods to teach specific nursing education content on junior-level nursing students' cognitive skills and confidence.	Undergraduate (Baccalaureate)	107	1st	IG 28.6 (8.4) CG 28.3 (7.2)	IG 50 (93) CG 51 (96) All 101 (79,53)
9	13	Brown 2009	The effect of simulation learning on critical thinking and self-confidence when incorporated into an electrocardiogram nursing course	Clinical Simulation in Nursing	1.277	USA	To demonstrate the effect of simulation activities on critical thinking and self-confidence in an electrocardiogram nursing course	Undergraduate (Baccalaureate)	140	4th	IG 28.00 (nd) CG 26.70 (nd) All 27.50 (nd)	IG 62 (89) CG 62 (89) All 62 (89)
10a **10b** **10c** **10d**	14 15 16 17	Chen 2015	Evaluating the impact of high□and low□fidelity instruction in the development of auscultation skills.	Medical Education	4.005	Canada	To explore the effectiveness of HF and low-fidelity instruction on tasks that are chosen to deliberately test skills close to, and more removed from, the clinical environment, within the clinical domains of cardiac and respiratory auscultation and physical assessment skill development.	Undergraduate (Bachelor)	42 (a) 33 (b) 42 (c) 33 (d)	3rd	Nd	nd
11	18	Cobbett 2016	Virtual versus face-to-face clinical simulation in relation to student knowledge, anxiety, and self-confidence in maternal-newborn nursing: A randomized controlled trial.	Nurse Education Today	2.533	Canada	To compare the effectiveness of two maternal newborn clinical simulation scenarios; virtual clinical simulation and face-to-face high-fidelity manikin simulation.	Undergraduate (Bachelor)	84	3rd	25.0 (nd)	47 (84.0)
12	19	Corbridge 2010	Online learning versus simulation for teaching principles of mechanical ventilation to nurse practitioner students.	International Journal of Nursing Education Scholarship	1.04	USA	To determine differences in knowledge acquisition and student satisfaction between two methods of teaching mechanical ventilation to advanced practice nursing (APN) students: high-fidelity patient simulation versus an online, narrated PowerPoint presentation.	Postgraduate (Advanced Practice Nursing)	20	na	IG 34.5 (10.1) CG 39.2 (9.9)	Nd
13	20	Harris 2011	Simulation-enhanced pediatric clinical orientation.	Journal of Nursing Education	1.28	USA	To determine the effect of simulation-enhanced orientation on pediatric acute care examination scores and pediatric clinical course grades among junior-level baccalaureate nursing students.	Undergraduate (Baccalaureate)	71	1st	nd	nd
14a **14b**	21 22	Kang 2015	Comparison of knowledge, confidence in skill performance (CSP) and satisfaction in problem-based learning (PBL) and simulation with PBL educational modalities in caring for children with bronchiolitis.	Nurse Education Today	2.533	South Korea	To compare changes in nursing students' knowledge, confidence in skill performance (CSP), and satisfaction resulting from training using three educational modalities.	Undergraduate (Bachelor)	131(a) 136 (b)	4th	nd	nd
15	23	Kardong-Edgren 2009	VitalSim® versus SimMan®: A comparison of BSN student test scores, knowledge retention, and satisfaction.	Clinical Simulation in Nursing	1,277	USA	To verify if student satisfaction and knowledge gains are equivalent with a medium-fidelity simulator such as VitalSim® and a high-fidelity simulator such as SimMan®, and if they provide more overall student and program access to simulation.	Undergraduate (Bachelor)	89 (a)	1st	nd	nd
16	24	King 2011	Teaching advanced cardiac life support protocols	Nurse Educator	1.372	USA	To compare the effectiveness of static simulation to high-fidelity simulation when teaching advanced cardiac life support guidelines	Undergraduate (Bachelor)	49	4th	nd	nd
17	25	Lapkin 2011	A cost–utility analysis of medium vs. high□fidelity human patient simulation manikins in nursing education.	Journal of Clinical Nursing	1.214	Australia	To determine whether the extra costs associated with high-fidelity manikins can justify the differences, if any, in the outcomes of clinical reasoning, knowledge acquisition and student satisfaction.	Undergraduate (Bachelor)	352	2nd (268) 3rd (84)	nd	299 (85.00)
18	26	Lee	Effects of high□fidelity patient simulation led clinical	Japan Journal	0.554	South	To examine effects of high-fidelity patient simulation (HFPS) led	Undergraduate	49	4th	nd	nd

		2016	reasoning course: Focused on nursing core competencies, problem solving, and academic self□efficacy.	of Nursing Science		Korea	clinical reasoning course among undergraduate nursing students.	(Bachelor)				
19	27	Lee 2017	Effects of pre□education combined with a simulation for caring for children with croup on senior nursing students.	Nursing & Health Sciences	1.17	South Korea	Educational outcomes were compared between groups that received education through simulation combined with pre-education, simulation alone, and preeducation alone.	Undergraduate (Bachelor)	87	4th	nd	nd
20a 20b	28 29	Liaw 2010	Developing clinical competency in crisis event management: An integrated simulation problem-based learning activity.	Advances in Health Sciences Education	1.06	Singapore	To evaluate the integration of a simulation-based learning activity on nursing students' clinical crisis management performance in a problem-based learning (PBL) curriculum.	Undergraduate (Baccalaureate)	30 (a) 33 (b)	1st	20.0 (1.0)	nd
21a 21b	30 31	Luctkar-Flude 2012	Evaluating high-fidelity human simulators and standardized patients in an undergraduate nursing health assessment course.	Nurse Education Today	2.533	Canada	To investigate learners' satisfaction, self-efficacy and performance behaviors among high-fidelity human simulators (HFPS), standardized patients (SP) and community volunteers (CV).	Undergraduate (Bachelor)	30 (a) 28 (b)	2nd	nd	nd
22	32	Merriman 2014	Comparing the effectiveness of clinical simulation versus didactic methods to teach undergraduate adult nursing students to recognize and assess the deteriorating patient.	Clinical Simulation in Nursing	1.277	UK	To evaluate the effectiveness of clinical simulation compared to classroom teaching in the assessment of the deteriorating patient.	Undergraduate (Bachelor)	34	1st	nd	nd
23	33	Montgomery 2012	Student satisfaction and self-report of CPR competency: Heart-Code™ BLS courses, instructor-led CPR courses, and monthly voice advisory manikin practice for CPR skill maintenance	International Journal of Nursing Education Scholarship	1.04	USA	To evaluate the effects of brief monthly refresher training on CPR skill retention, confidence, and satisfaction with CPR skill level of nursing students.	Undergraduate (Baccalaureate) Postgraduate (Diploma, Associate)	341	1st na	nd	nd
24	34	Oldenburg 2013	Traditional clinical versus simulation in 1st semester clinical students: students' perceptions after a 2nd semester clinical rotation.	Clinical Simulation in Nursing	1.277	USA	To analyze the immediate and long-term impact on students' perception of clinical competence after high-fidelity simulation.	Undergraduate (Baccalaureate)	95	1st	nd	nd
25	35	Powell-Laney 2012	The use of human patient simulators to enhance clinical decision-making of nursing students.	Education for Health	0.56	USA	To assess if HPS technology leads to greater clinical decision-making ability and clinical performance compared to the teaching modality of a paper and pencil case study.	Undergraduate (Licensed Practical Nursing)	133	na	32.00 (nd)	117 (88.00)
26	36	Rodgers 2009	The effect of high-fidelity simulation on educational outcomes in an advanced cardiovascular life support course.	Simulation in Healthcare	1.615	USA	To determine subjects' educational outcomes through videos of subjects performing a simulated cardiac arrest after the conclusion of the course.	Undergraduate (Baccalaureate) Postgraduate (Associate)	34	4th na	32.5 (nd)	29 (86.5)
27	37	Roh 2014	Effects of high-fidelity patient simulation on nursing students' resuscitation-specific self-efficacy.	CIN: Computers, Informatics, Nursing	1.301	South Korea	To assess the difference in pre- and post-test self-efficacy after simulation training and to compare differences in between nursing students exposed to medium- or high-fidelity patient simulations.	Undergraduate (Baccalaureate)	163	2nd	IG 22.39 (5.89) CG 21.312 (3.97)	IG 25 (89.3) CG 125 (92.6)
28	38	Scherer 2007	A comparison of clinical simulation and case study presentation on nurse practitioner students' knowledge and confidence in managing a cardiac event.	International Journal of Nursing Education Scholarship	1.04	USA	to compare the efficacy of controlled simulation mannequin (SM) assisted learning and case study presentation on knowledge and confidence of nurse practitioner (NP) students in managing a cardiac event	Postgraduate (Acute Care Nurse Practitioner, Adult Nurse Practitioner)	23	na	nd	nd
29	39	Shinnick 2014	Does Nursing Student Self-Efficacy Correlate with Knowledge When Using Human Patient Simulation?	Clinical Simulation in Nursing	1.277	USA	To demonstrate self-efficacy and knowledge gain in subjects who participated in high-fidelity simulation	Undergraduate (Baccalaureate)	161	4th	25.70 (nd)	142 (88.20)
30a 30b	40 41	Smith 2012	High-fidelity simulation and legal/ethical concepts: A transformational learning experience.	Nursing Ethics	1.755	USA	To compare the new HFHS experience with in-person and online student groups using the same case	Undergraduate (Baccalaureate)	33 (a) 26 (b)	3rd	nd	nd
31	42	Tubaishat 2014	Effect of cardiac arrhythmia simulation on nursing students' knowledge acquisition and retention	Western Journal of Nursing Research	1.313	Jordan	To evaluate the effect of simulation-based teaching on acquisition and retention of arrhythmia-related knowledge among nursing students	Undergraduate (Bachelor)	91	4th	20.4 (0.98)	56 (56)
32	43	Tuzer 2016	The effects of using high-fidelity simulators and standardized patients on the thorax, lung, and cardiac examination skills of undergraduate nursing students.	Nurse Education Today	2.533	Turkey	To compare the effects of the use of a high-fidelity simulator and standardized patients on the knowledge and skills of students conducting thorax-lungs and cardiac examinations, and to explore the students' views and learning experiences	Undergraduate (Baccalaureate)	52	1st	23.00 (nd)	(88.50)
33	44	White 2013	Comparison of instructional methods: Cognitive skills and confidence levels.	Clinical Simulation in Nursing	1.277	USA	To compare the effectiveness of two instructional methods (traditional classroom method and high-fidelity simulator method) to teach content related to distributive shock.	Undergraduate (Baccalaureate)	54	nd	nd	IG 16 (100) CG 31 (82)

NICE **Quality Appraisal Checklist for Quantitative Intervention Studies**

SECTION 1: POPULATION
1.1 Is the source population or source area well described? Was the country, setting, location (urban, rural), population demographics etc. adequately described?
1.2 Is the eligible population representative of the source population? Was the recruitment well defined? Was the population representative of the source?
1.3 Do the selected participants or areas represent the eligible population or area? Was the method of selection of participants from the eligible population well described? What % of selected individuals or clusters agreed to participate? Were there any sources of bias? Were the inclusion or exclusion criteria explicit and appropriate?
SECTION 2: METHOD OF ALLOCATION TO INTERVENTION (OR COMPARISON)
2.1 Allocation to intervention (or comparison). How was selection bias minimised? Was allocation to exposure and comparison randomised? Was it truly random ++ or pseudo-randomised + (e.g. consecutive admissions)? If not randomised, was significant confounding likely (−) or not (+)? If a cross-over, was order of intervention randomised?
2.2 Were interventions (and comparisons) well described and appropriate? Were interventions and comparisons described in sufficient detail? Were comparisons appropriate?
2.3 Was the allocation concealed? Adequate allocation concealment (++) would include centralised allocation or computerised allocation systems.
2.4 Were participants or investigators blind to exposure and comparison? Were those delivering or assessing the intervention kept blind to intervention allocation? (Triple or double blinding score ++). If lack of blinding is likely to cause important bias, score −.
2.5 Was the exposure to the intervention and comparison adequate? Is reduced exposure to intervention or control related to the intervention or fidelity of implementation?
2.6 Was contamination acceptably low? Did any in the comparison group receive the intervention or vice versa? If so, was it sufficient to cause important bias? If a cross-over trial, was there a sufficient wash-out period between interventions?
2.7 Were other interventions similar in both groups? Did either group receive additional interventions or have services provided in a different manner? Were the groups treated equally by researchers or other professionals? Was this sufficient to cause important bias?
2.8 Were all participants accounted for at study conclusion? Were those lost-to-follow-up <20%? Did the proportion dropped differ by group?
2.9 Did the setting reflect usual practice? Did the setting in which the intervention or comparison was delivered differ significantly from usual practice? For example, did participants receive intervention (or comparison) condition in a hospital rather than a community-based setting?
2.10 Did the intervention or control comparison reflect usual practice? Did the intervention or comparison differ significantly from usual practice?
SECTION 3: OUTCOMES
3.1 Were outcome measures reliable? Were outcome measures subjective or objective? How reliable were measures? Was there any indication that measures had been validated?
3.2 Were all outcome measurements complete? Were all or most study participants who met the defined study outcome definitions likely to have been identified?
3.3 Were all important outcomes assessed? Were all important benefits and harms assessed? Was it possible to determine the overall balance of benefits and harms?
3.4 Were outcomes relevant? Where surrogate outcome measures were used, did they measure what they set out to measure?
3.5 Were there similar follow-up times in exposure and comparison groups? If groups are followed for different lengths of time, then more events are likely to occur in the group followed-up for longer distorting the comparison. Analyses can be adjusted to allow for differences in length of follow-up.
3.6 Was follow-up time meaningful? Was follow-up long enough to assess long-term benefits or harms? Was it too long, e.g. participants lost to follow-up?
SECTION 4: ANALYSES
4.1 Were groups similar at baseline? If not, were these adjusted? If so, were these adjusted for in the analyses (e.g. multivariate analyses or stratification)
4.2 Was intention to treat analysis conducted? Were all participants (including dropped out or did not complete the intervention) analysed?
4.3 Was the study sufficiently powered to detect an intervention effect? A power of 0.8 is the conventional standard. Is a power calculation presented?
4.4 Were the estimates of effect size given or calculable? Were effect estimates (e.g. relative risks, absolute risks) given or possible to calculate?
4.5 Were the analytical methods appropriate? Were important differences in follow-up time and likely confounders adjusted for? Were subgroup analyses pre-specified?
4.6 Was the precision of intervention effects given or calculable? Were they meaningful? Were CIs or p values for effect estimates given or possible to calculate?

Quality appraisal of included studies according to NICE checklist

Items / N	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	3.1	3.2	3.3	3.4	3.5	3.6	4.1	4.2	4.3	4.4	4.5	4.6	EV	IV
1	-	-	-	+	++	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	-	-	+	+	-	+
2	++	-	-	+	+	-	-	+	-	+	+	++	+	-	+	+	+	+	+	+	-	++	+	+	+	-	+
3	++	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	-	+
4	++	++	++	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
5	++	++	++	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
6	++	-	-	++	+	+	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	-	+
7	-	-	-	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	-	-	-	+	+	-	+
8	++	+	+	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	++	+	+	+	+	+
9	++	-	-	+	+	-	-	+	-	+	+	++	+	+	+	+	+	+	+	+	++	++	+	+	+	-	+
10	-	-	-	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	-	++	+	+	+	-	+
11	++	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	+	++	+	+	+	-	+
12	+	+	+	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	++	+	+	+	+	+
13	-	-	-	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	++	++	+	+	+	-	+
14	-	++	++	-	++	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
15	-	+	+	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	++	+	+	+	+	+
16	-	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	++	++	+	+	+	-	+
17	+	-	-	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
18	-	+	+	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	-	-	+	+	+	+
19	+	+	+	-	++	-	-	+	-	+	+	-	+	-	+	+	+	+	+	-	-	-	-	+	+	+	+
20	+	-	-	-	++	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	++	++	+	+	+	-	+
21	-	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	++	++	+	+	+	-	+
22	-	-	-	++	++	+	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
23	++	-	-	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
24	-	-	-	-	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
25	++	+	+	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	++	++	+	+	+	++	+
26	++	-	-	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
27	++	++	++	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
28	-	+	+	+	++	-	-	+	na	+	+	++	+	-	+	+	+	+	+	+	++	++	+	+	+	+	+
29	++	++	++	++	+	+	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	-	-	+	+	++	+
30	-	-	-	+	++	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
31	++	+	+	+	+	+	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
32	++	-	-	++	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
33	+	++	++	++	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	++	-	-	+	+	++	+

na: not applicable; nr: not reported; EV: external validity; IV: internal validity.

List of study design feature checking (studies with allocation to interventions at the individual level)

N / Items	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]
a1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
a2	Y	Y	Y	Y	Y	N	N	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	Y
b1	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	N	Y	N	N
b2	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	N	N	N	Y	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y
b3	N	N	N	N	N	N	N	P	N	Y	N	N	N	P	N	N	N	P	P	Y	N	N	N	P	N	Y	P	N	N	N	N	N	N
b4	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
b5	N	N	N	N	N	N	N	P	N	N	N	N	N	P	N	N	N	P	P	P	N	N	N	P	N	P	P	N	N	N	N	N	N
b6	N	N	N	N	N	N	N	P	N	N	N	N	N	P	N	N	N	P	P	N	N	N	N	P	N	N	P	N	N	N	N	N	N
b7	N	N	N	N	N	N	N	P	N	N	N	N	N	P	N	N	N	P	P	N	N	N	N	P	N	N	P	N	N	N	N	N	N
b8	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
c1	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	P	Y	Y	Y	Y	Y	Y
c2	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	P	Y	Y	Y	Y	Y	Y
c3	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	P	Y	Y	Y	Y	Y	Y
c4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
d1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
d2	P	P	P	P	P	P	P	Y	P	P	P	P	P	Y	P	P	P	Y	Y	P	Y	P	Y	Y	Y	P	Y	Y	P	Y	P	Y	Y
	Q-RCT	Q-RCT	Q-RCT	Q-RCT	Q-RCT	RCT	Q-RCT	CBA	Q-RCT	NRCT	Q-RCT	Q-RCT	Q-RCT	CBA	Q-RCT	Q-RCT	Q-RCT	CBA	CBA	NRCT	Q-RCT	RCT	Q-RCT	CBA	Q-RCT	NRCT	CBA	Q-RCT	RCT	Q-RCT	RCT	Q-RCT	Q-RCT

Notes: Was there a comparison: (a) [between two or more groups of participants receiving different interventions? (a1)], [within the same group of participants over time? (a2)]. Were participants allocated to groups by: (b) [concealed randomization? (b1)], [quasi-randomization? (b2)], [by other action of researchers? (b3)], [time differences? (b4)], [location differences? (b5)], [treatment decisions? (b6)], [participants' preferences? (b7)], [based on outcome? (b8)]. Which parts of the study were prospective? (c) [identification of participants? (c1)], [assessment of baseline and allocation to intervention? (c2)], [assessment of outcomes? (c3)], [generation of hypotheses? (c4)]. On what variables was comparability between groups assessed: (d) [potential confounders? (d1)], [baseline assessment of outcome variables? (d2)].
Y: yes; N: no; P: possible; RCT: randomized controlled trial; Q-RCT: quasi-RCT; NRCT: non-RCT; CBA: controlled before-after.
Note: studies in the first column are labeled with the corresponding number exhibited in the previous 'Description of included studies'.

Coding protocol for data extraction

Study (n), Scenario	Tool	Experimental	Control	N (IG /CG)	IG	CG	Statistical test	*p*
Self-rated Knowledge (n = 12, k = 13)								
[1] Cardiac arrest	14-item Multiple-choice [AHA, 2005c]	Laerdal SimMan®	No intervention	32/33	12.25 (1.22)	11.52 (1.15)	F test	0.015
[3] Cardiac arrest	12-item Multiple-choice [AHA, 2010]	METI™ version 6	Static half-torso manikin (Low-fidelity manikin)	52/58	9.10 (nd)	8.60 (nd)	Independent t-test	0.1
					t = 1.6			
[5] Cardiac arrest	14-item Multiple-choice [AHA, 2010]	METI™	Low-fidelity manikin	45/45	12.67 (1.06)	11.22 (0.90)	Independent t-test	≤0.001
[11] Preeclampsia	10-item Multiple-choice	HFPS	Laerdal vSim® (Medium-fidelity manikin)	42/42	4.80 (1.19)	4.12 (1.54)	Independent t-test	0.09
[12] Respiratory failure	12-item Multiple-choice	Laerdal SimMan®	Web-based learning	10/10	9.20 (1.30)	9.10 (1.70)	Independent t-test	0.891
[14a] Bronchiolitis	20-item Dichotomous	HFPS	Problem-based learning	62/69	0.86 (0.07)	0.83 (0.07)	nd	nd
[14b] Bronchiolitis	20-item Dichotomous	HFPS	Lecture	62/74	0.86 (0.07)	0.78 (0.11)	nd	nd
[19] Pulmonary edema	10-item Dichotomous	Laerdal SimMan®	Lecture	45/42	5.31 (1.29)	5.21 (1.47)	ANOVA	<0.001
[26] Cardiac arrest	ACLS Written Examination [AHA]	Laerdal SimMan®	Low-fidelity manikin	16/18	90.00 (7.59)	87.78 (9.05)	Mann-Whitney U test	0.447
[29] Heart failure, Pulmonary edema	12-item Multiple-choice HF Clinical Knowledge	Laerdal SimMan®	No intervention	89/72	61.39 (12.71)	55.47 (14.77)	Nd	nd
[31] Arrhythmia	20-item Multiple-choice [AHA, 2010]	METI™ version 6	Lecture	47/44	13.20 (3.35)	7.60 (2.36)	Independent t-test	≤0.001
[32] Intensive care	22-item Multiple-choice	HFPS	Standardized patient	26/26	72.79 (9.13)	73.80 (11.28)	Nd	nd
[33] Shock	10-item Multiple-choice Distributive Shock Questionnaire (DSQ)	HFPS	Lecture	16/38	6.75 (1.61)	7.82 (1.45)	ANOVA	<0.03
Self-rated Self-confidence (n = 15, k = 18)								
[2a] Pneumonia	Ad-hoc	METI™	Lecture	35/34	4.05 (0.48)	3.86 (0.53)	ANCOVA	0.034
[2b] Increased intracranial pressure	Ad-hoc	METI™	Lecture	35/34	3.37 (0.41)	3.56 (0.34)	ANCOVA	0.093
[3] Cardiac arrest	17-item [Arnold, 2009]	METI™ version 6	Static half-torso manikin (Low-fidelity manikin)	52/58	Student t = 3.91		Independent t-test	0.001
[4c] Intensive care	Likert-type	Laerdal SimMan®	No intervention	49/50	3.40 (0.80)	3.50 (1.00)	Mann–Whitney	0.819
[6] Hypovolemic shock, Bradycardia, Pneumonia, Pulmonary edema	26-item Likert-type Gains Perceived with High-fidelity Simulation Scale (GPHSS) [Baptista, 2013]	Laerdal Resusci Anne with iStan®	Laerdal Resusci Anne with VitalSim® (Medium-fidelity manikin))	49/36	80.73 (7.03)	78.73 (4.76)	nd	nd
[8] Cardiac arrest	34-item Confidence Level (CL) [Madorin, 1999]	METI™	Lecture	54/53	106.29 19.71)	113.51 (17.87)	Independent t-test	0.09
[11] Preeclampsia	27-item Likert-type Nursing Anxiety and Self-Confidence with Clinical Decision-Making Scale (NASC-CDM)	HFPS	Laerdal vSim® (Medium-fidelity manikin)	42/42	115.25 21.95)	104.89 (17.52)	Independent t-test	0.059
[14a] Bronchiolitis	27-item Likert-type	HFPS	Problem-based learning	62/69	3.57 (0.33)	3.69 (0.30)	nd	nd
[14b] Bronchiolitis	20-item Dichotomous	HFPS	Lecture	62/74	3.57 (0.33)	3.38 (0.44)	nd	nd
[18] Cardiac arrest	70-item Likert-type Nursing core competencies measurement tool [Lee, 2011]	Laerdal SimMan®	No intervention	23/26	256.47 32.33)	247.26 (23.17)	Fisher's exact test	0.008
[19] Pulmonary edema	13-item Likert-type	Laerdal SimMan®	Lecture	45/42	4.06 (0.47)	3.82 (0.55)	ANOVA	0.011
[21a] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Role-play	14/16	3.50 (0.94)	4.31 (1.01)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	3.50 (0.94)	4.21 (0.70)	nd	nd
[22] Intensive care	33-item Likert-type Nursing Competencies Questionnaire [Bartlett, 1998]	HFPS	Lecture	15/19	84.40 (1.20)	81.21 (2.70)	Mann-Whitney U test	<0.01
[23] Cardiac arrest	5-item Likert-type	HFPS	Lecture	165/176	146/19 *	136/40 *	nd	nd
[24] Intensive care	5-item Likert-type	HFPS	No intervention	64/31	20.31 (2.13)	18.65 (2.65)	Independent t-test	<0.001
[29] Heart failure, Pulmonary edema	3-item Likert-type [Ravert, 2004]	Laerdal SimMan®	No intervention	89/72	2.47 (0.86)	2.08 (0.97)	nd	nd
[33] Shock	34-item Likert-type [Madorin, 1999]	HFPS	Lecture	16/38	111.38 16.27)	108.26 (14.55)	nd	>0.05
Self-rated Self-efficacy (n = 4, k = 5)								
[18] Cardiac arrest	28-question Likert-type Academic self-efficacy tool [Kim, 2001]	Laerdal SimMan®	No intervention	23/26	114.83 13.90)	110.19 (13.15)	Fisher's exact test	0.167
[21a] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Role-play	14/16	18.79 (4.17)	21.63 (3.30)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	18.79 (4.17)	19.50 (3.01)	nd	nd
[22] Intensive care	Likert-type General Perceived Self-Efficacy Scale (GPSES) [Schwarzer, 1997]	HFPS	Lecture	15/19	148.0 (14.80)	149.0 (10.76)	nd	nd
[27] Cardiac arrest	Resuscitation Self-Efficacy Scale [Roh, 2012]	Laerdal SimMan®	Laerdal Resusci Anne® (Low-fidelity manikin)	28/135	3.82 (0.39)	3.45 (0.58)	Independent t-test	<0.001

Self-rated Satisfaction with simulation (n = 10, k = 13)								
[6] Hypovolemic shock, Bradycardia, Pneumonia, Pulmonary edema	17-item Likert-type Satisfaction with Clinical Experience Simulation Scale (SCESS)	Laerdal Resusci Anne with iStan®	Laerdal Resusci Anne with VitalSim® (Medium-fidelity manikin)	49/36	89.37 (6.18)	84.88 (6.98)	nd	nd
[12] Respiratory failure	5-item Likert-type	Laerdal SimMan®	Web-based learning	10/10	24.6 (0.97)	19.3 (2.90)	Independent t-test	<0.0001
[14a] Bronchiolitis	18-item Likert-type Satisfaction with Simulation Experience Scale (SSE)	HFPS	Problem-based learning	62/69	4.17 (0.53)	4.67 (0.39)	nd	nd
[14b] Bronchiolitis	20-item Dichotomous	HFPS	Lecture	62/74	4.17 (0.53)	3.48 (0.62)	nd	nd
[15a] Cardiac arrest	7-item Likert-type	Laerdal SimMan®	Laerdal VitalSim® (Medium-fidelity manikin)	45/44	4.58 (0.44)	4.50 (0.48)	nd	nd
[17] Hypervolemia, Pulmonary edema	18-item Likert-type Satisfaction with Simulation Experience Scale (SSE)	Laerdal SimMan®	MegaCode Kelly™ with VitalSim™ (Medium-fidelity manikin)	352/352	4.51 (0.37)	4.42 (0.42)	Independent t-test	0.546
[19] Pulmonary edema	9-item Likert-type [Otieno, 2007]	Laerdal SimMan®	Lecture	45/42	3.39 (0.42)	3.03 (0.36)	ANOVA	<0.001
[21a] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Role-play	14/16	40.86 (6.71)	46.38 (5.97)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	40.86 (6.71)	41.00 (12.20)	nd	nd
[23] Cardiac arrest	5-item Likert-type	HFPS	Lecture	165/176	153/12	156/20	nd	nd
[28] Cardiac arrest	6-item Likert-type Open-ended Evaluation Instrument	Med Sim–Eagle	Lecture	13/10	2.85 (0.39)	2.85 (0.42)	Independent t-test	0.784
[30a] Cardiac arrest	1-item Likert-type	HFPS	Lecture	16/17	4.50 (0.73)	4.20 (0.75)	nd	nd
[30b] Cardiac arrest	1-item Likert-type	HFPS	Web-based learning	16/10	4.50 (0.73)	3.60 (0.52)	nd	nd
Observed Performance (n = 14, k = 21)								
[1] Cardiac arrest	BLS for Healthcare Provider Course Final Evaluation Skills Sheet for Adult CPR [AHA, 2001]	Laerdal SimMan®	No intervention	32/33	13.19 (0.78)	11.36 (1.27)	F test	0.000
[4a] Intensive care #1	Ad-hoc	Laerdal SimMan®	No intervention	49/50	47.54 (8.46)	48.82 (10.26)	nd	nd
[4b] Intensive care #2	Ad-hoc	Laerdal SimMan®	No intervention	49/50	61.71 (7.53)	56.00 (9.46)	nd	nd
[5] Cardiac arrest	AHA BLS for Healthcare Provider Course Final Evaluation Skills Sheet for Adult CPR [AHA, 2005c]	METI™	Low-fidelity manikin	45/45	13.13 (1.01)	11.58 (1.63)	Independent t-test	≤0.001
[7a] Cardiac arrest, Pulmonary embolism, COPD	7-item Likert-type	HFPS	No intervention	11/6	5.04 (0.48)	3.64 (1.22)	ANOVA	<0.05
[7b] Cardiac arrest, Pulmonary embolism, COPD	7-item Likert-type	HFPS	Video-watching	11/10	5.04 (0.48)	4.74 (0.88)	ANOVA	>0.05
[8] Cardiac arrest	20-item Acute Myocardial Infarction Questionnaire (AMIQ)	METI™	Lecture	54/53	15.58 (2.13)	14.17 (1.86)	Independent t-test	0.002
[9] Dysrhythmias	30-item Multiple-choice ECG SimTest [Morrison, 2006]	Laerdal SimMan®	Lecture	70/70	1008.00 (nd)	1070.00 (nd)	Independent t-test	0.143
[10a] Heart failure	7-item Likert-type	METI BabySIM®	Audio listening	21/21	3.41 (0.33)	3.71 (0.30)	nd	nd
[10b] Heart failure	7-item Likert-type	METI BabySIM®	No intervention	21/12	3.41 (0.33)	3.23 (0.35)	nd	nd
[10c] Pneumothorax	7-item Likert-type	METI PediaSIM®	Audio listening	21/21	3.39 (0.32)	3.50 (0.29)	nd	nd
[10d] Pneumothorax	7-item Likert-type	METI PediaSIM®	No intervention	21/12	3.39 (0.32)	3.60 (0.34)	Nd	nd
[13] Bronchiolitis, Dehydration, Respiratory distress	RN Nursing Care of Children Content Mastery Test [Assessment Technologies Institute, 2008]	Laerdal SimBaby™ METI PediaSim®	No intervention	55/16	65.33 (6.86)	67.46 (8.45)	Independent t-test	0.19
[16] Cardiac arrest	25-item Multiple-choice [AHA, 2006]	Laerdal SimMan®	Low-fidelity manikin	24/25	22 (92.00%)	23 (93.00%)	nd	nd
[20a] Respiratory distress	Dichotomous	Laerdal SimMan®	Problem-based learning	13/17	20.08 (1.93)	18.19 (2.55)	Independent t-test	0.034
[20b] Cardiac arrest	Dichotomous	Laerdal SimMan®	Problem-based learning	18/15	27.56 (2.15)	23.07 (2.69)	Independent t-test	0.00
[21a] Asthma exacerbation	47-item Dichotomous Respiratory Assessment Checklist	HFPS	Role-play	14/16	32.90 (4.20)	28.90 (4.50)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	32.90 (4.20)	27.40 (4.90)	nd	nd
[22] Intensive care	24-item Dichotomous	HFPS	Lecture	15/19	19.00 (3.20)	16.00 (3.70)	nd	nd
[25] Cardiac arrest	Nd	Laerdal SimMan®	Lecture	66/67	69.70 (12.20)	61.60 (13.70)	Independent t-test	<0.001
[26] Cardiac arrest	ACLS Mega Code Performance Score Sheet [AHA]	Laerdal SimMan®	Low-fidelity manikin	16/18	73.60 (17.70)	64.60 (15.60)	nd	nd

*: no. of students with correct/incorrect outcome data.

Note: studies in the first column are labeled with the corresponding number exhibited in the previous 'Description of included studies'.

PRISMA 2009 Checklist

PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	2
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	2-3
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	3
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	3; Supplementary file
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	3
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	3-4
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	4
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	4
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	4
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	4
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	4
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	4
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	4-5
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	5; Supplementary file
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	6
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	6
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	6
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	6
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	6
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	6-8
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	8
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	8-9
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	9

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Effects of high-fidelity simulation based on life-threatening clinical condition scenarios on learning outcomes of undergraduate and postgraduate nursing students: a systematic review and meta-analysis

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Title: Effects of high-fidelity simulation based on life-threatening clinical condition scenarios on learning outcomes of undergraduate and postgraduate nursing students: a systematic review and meta-analysis

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ABSTRACT

Objective. The purpose was to analyse the effectiveness of high-fidelity patient simulation (HFPS) based on life-threatening clinical condition scenarios on undergraduate and postgraduate nursing students' learning outcomes.

Design. A systematic review and meta-analysis were conducted based on the Cochrane Handbook for Systematic Reviews of Interventions and its reporting was checked against the PRISMA checklist.

Data sources. PubMed, Scopus, CINAHL with Full Text, Wiley Online Library, and Web of Science were searched through July 2017. Author contact, reference, and citation lists were checked to obtain additional references.

Study selection. To be included, available full-texts had to be published in English, French, Spanish or Italian and: (a) involved undergraduate or postgraduate nursing students performing HFPS based on life-threatening clinical condition scenarios; (b) contained control groups not tested on the HFPS before the intervention; (c) contained data measuring learning outcomes such as performance, knowledge, self-confidence, self-efficacy or satisfaction measured just after the simulation session; and (d) reported data for meta-analytic synthesis.

Review method. Three independent raters screened the retrieved studies using a coding protocol to extract data in accordance with inclusion criteria.

Synthesis method. For each study, outcome data were synthesized using meta-analytic procedures based on random-effect model and computing effect sizes by Cohen's *d* with a 95% confidence interval.

Results. Thirty-three studies were included. HFPS sessions showed significantly larger effects sizes for knowledge (*d* = 0.49, 95% CI [0.17; 0.81]) and performance (*d* = 0.50, 95% CI [0.19; 0.81]) when compared with any other teaching method. Significant heterogeneity among studies was detected.

Limitations. Only a few studies had an experimental design, therefore generalizability of results is limited.

Conclusions. Compared to other teaching methods, HFPS revealed higher effects sizes on nursing students' knowledge and performance. Further studies are required to explore its effectiveness in improving nursing students' competence and patient outcomes.

Strengths and limitations of this study

- This meta-analysis provides data on the impact of HFPS sessions based on life-threatening clinical scenarios on knowledge, performance, satisfaction, self-confidence, and self-efficacy in undergraduate and postgraduate nursing students.
- A structured search strategy was utilized across multiple databases.
- Data heterogeneity and limited amount of high-quality primary studies limit the generalizability of results in nursing education practice.

INTRODUCTION

Health care systems and health needs of general population worldwide require newly registered nurses to have adequate knowledge, skills, and attitudes in order to be 'fit for practice'.[1 2] The clinical training of nursing students plays an essential role in the learning process during undergraduate courses,[3] but the unpredictable nature of the clinical training environment can generate risk of error potentially harmful for both nursing students [4 5] and patients.[6 7] Since available evidence assume that the safety for both patients and learners rises together with the growth of students' clinical expertise,[4-8] an active learning method may allow nursing students to practice clinical procedures learned in theory and patients to receive best-quality safe care.[9 10] Unfortunately, the organizational issues and short rotations in clinical settings do not always allow nursing students to train in an interactive way especially in high-risk, low incidence clinical events.[11] All these reasons have generated the need for integrative teaching methods, such as high-fidelity patient simulation (HFPS). The HFPS, especially when performed according to acknowledged standards, [12] utilizes technologically improved manikins that are able to breathe, talk, and have both heart and lung sounds, programmed by algorithms or dynamic 'off-the-cuff' instructions to replicate the physiological parameters in normal or deteriorating patients.[13] This method allows for giving and receiving feedback on repeated actions permitting the shift from theory to lived experience for the student within a safe learning environment rich with opportunities.[14 15] The use of high-fidelity patient simulators has been shown to improve nursing students' learning outcomes, such as satisfaction, self-confidence, and self-efficacy,[16] as well as knowledge and performance [17 18] by means of deliberate practices, feedback opportunities, and gradually augmented task difficulties.[19] Moreover, the usefulness of the forgiving nature of the simulation environment is often acknowledged and appreciated by students who experience

HFS sessions.[16] Consequently, HFPS has become an important learning strategy in nursing education [3 6 20 21] since it provides the opportunity to frequently experience acute clinical situations without risk to the patient or learner.[20 22 23]

Although primary studies widely documented the potential of HFPS to improve nursing students' learning outcomes,[18 24 25] literature did not focus on the effectiveness of the simulation when based on life-threatening clinical scenarios referred to different clinical settings. Therefore, considering the increase of published studies on the effectiveness of HFPS in academic nursing education, a systematic analysis of these studies is expected to allow the development of guidelines in this field.

Objectives

The aim of this systematic review was to analyse the effectiveness of HFPS based on life-threatening clinical condition scenarios in improving the learning outcomes of knowledge, self-confidence, satisfaction, self-efficacy, and performance for undergraduate and post-graduate nursing students.

METHODS

A systematic review and meta-analysis were conducted based on the Cochrane Handbook for Systematic Reviews of Interventions [26] and its reporting was checked against the PRISMA checklist. [27]

Eligibility and inclusion criteria

In order to be included in this analysis, the abstract had to clearly indicate the study: (a) was experimental or quasi-experimental; (b) had utilized HFPS and (c) had involved nursing students (undergraduate or postgraduate). Available full-texts had to be published in English, French, Spanish or Italian language and studies had to include: (a) HFPS based on critical care scenarios; (b) control groups not tested on the HFPS before the intervention; (c) data on the learning outcomes of performance, knowledge, self-confidence, self-efficacy or satisfaction measured just after the simulation session; and (d) data for meta-analytic synthesis. For the purpose of this systematic review, the concept of knowledge was intended as deliver of the theoretical basis of caring,[28] self-confidence is defined as trusting the soundness of one's own judgment and performance,[23] satisfaction is considered the fulfilment of student's expectations during the simulation experience,[29] self-efficacy consists of the way students perceive, think, and motivate themselves when learning and performing clinical training,[30] and, finally, performance is the student's ability to demonstrate clinical skills.[31]

Information sources and search

A pilot search was performed to identify keywords and MeSH headings relevant for the electronic research. PubMed, Scopus, CINAHL with Full Text, Wiley Online Library, and Web of Science were searched until July 2017 using the search strategies listed in the Box of the supplementary file. To perform an exhaustive search, reference and citation lists from included studies were checked for other relevant references. Thomson Reuters EndNote® X7 was used for the management of the retrieved studies and references.

Study selection

Titles and abstracts were screened by three raters (CLC, AD, and VC) for eligibility according to the listed criteria and, for each eligible study, full-texts were retrieved by using online databases and faculty

interlibrary service, as well as by contacting authors. Full-texts were analysed by two raters (CLC and AD) for their inclusion in the review based on the described criteria. Both in the eligibility and inclusion stage, the agreement among the judgements of the authors (inter-rater reliability) was estimated with the Krippendorff's alpha coefficient (α) ranging from 0 (totally disagree) to 1 (totally agree).[32] Any disagreement between the raters was resolved by discussion until consensus was reached.

Data collection process

For the purposes of this systematic review, a coding protocol was designed by the research team and developed with a spread sheet built with Microsoft Excel. To obtain an accurate version of the tool, the form was tested independently by two authors (CLC and AD).

Data items and quality appraisal of individual studies

Data related to year of publication, study design, country, sample size, participants characteristics, simulator features, control conditions, scenarios, outcomes and measurement tools, and time of exposure to scenarios were extracted independently by two authors (AD and CLC). Krippendorff's alpha was used to calculate inter-rater reliability and any disagreement about data extraction was resolved by discussing with a third author (LL) to gain consensus.[32] The study designs were checked with 'List of study design features'.[26] The included studies were screened for their methodological quality through the Quality Appraisal Checklist for Quantitative Intervention Studies designed by the National Institute for Health and Care Excellence (NICE) [33] shown in the Table A of the supplementary file. To provide a global measure for both external and internal validity, the most frequent judgment was utilized. The quality of the studies was not deemed to be an exclusion criterion.

Synthesis of results and summary measures

For each study, the outcome data were synthesized through meta-analytic procedures using the software ProMeta 3.0. The random-effect model was used for all studies as a conservative approach to account for different sources of variation among studies (between-studies and within-study variance).[34 35] As Cohen's *d* (standardized mean difference) permits meta-analysis even when studies have used different original measures, it was directly computed or derived.[36 37] In this regard, standardization has been the only way to carry out a meta-analysis, considering multiple measurement instruments found in included studies.[37] Effect sizes were pooled across studies to obtain an overall effect size with the inverse-variance method. For each effect size, the corresponding 95% confidence interval (CI), weight, and statistical significance were calculated. The pooled effect size significantly favoured the HFPS when Cohen's *d* was higher than '0' and its 95% CI did not overlap the 0-line. Values of Cohen's can be interpreted as a small effect (0.2), medium effect (0.5), and large (0.8).[37] In order to assess the significance of the difference between the means of HFPS and the other teaching methods, a Z-test was performed for each meta-analysed outcome. The historical trends from the searched databases were graphed.

Risk of bias across studies and additional analyses

In order to evaluate the influence of each study on the overall effect sizes and to verify the robustness of the results, sensitivity analysis was undertaken through the leave-one-out approach.[26] Publication bias was

examined by the Egger's regression,[38] Trim and Fill, and the Fail-safe number methods were utilized to assess the effect of publication bias on effect size.[39] Since robust eligibility criteria were adopted and the reliability of data extraction was guaranteed by a multi-rater approach, data were presented considering any acceptable level of heterogeneity which was checked and measured with Q-test and I^2 and explored through sub-group analyses,[40] utilizing the 'scenario', 'manikin brand', and 'control intervention' as moderators. ProMeta 3.0 and IBM SPSS version 19.0 (IBM Corp., Armonk, New York, USA) were utilized for data analysis.

Patient and public involvement

This review had no contact with patients. All information was obtained from published studies.

RESULTS

Study selection

The search produced 2603 references from databases and 1857 studies from reference and citation searching, all published until July 2017. After removing duplicates, 2130 abstracts were screened for relevance. Consequently, 492 full-texts were analysed and 459 studies were excluded for not meeting the inclusion criteria (Figure 1).

Inter-rater reliability among the authors for abstracts and full-texts was 0.84 and 1.00 (Krippendorff's α coefficient), respectively, before consensus among authors was reached. The final sample of 33 studies originating 44 comparisons was included in this systematic review, as shown in the Table B of the supplementary file. It should be noted that a significant increase in the general number of studies (R^2 = 0.835; $p < 0.001$) occurred over the last 30 years about HFPS (Figure 1 of the supplementary file).

Study characteristics

Detailed information about study characteristics are presented in the Table C of the supplementary file. Summaries about more significant features of included studies are presented as follows.

Sample participants

The overall sample of nursing students (n = 3042) showed sample sizes varying from 17 to 352 participants composed of undergraduate (n = 2607; 85.7%) and postgraduate students (n = 435; 14.3%) and had a mean age of 25.7 (SD 5.8). Just over half of the studies (n = 19; 57.6%) were conducted in North America (USA n = 15, 45.5%; Canada n = 4, 12.1%), three studies (9.1%) in Europe (United Kingdom n = 2, 6.1%; Portugal n = 1, 3.0%), five studies (15.1%) were conducted in South Korea, three studies (9.1%) in Jordan, while three studies (9.1%) in other countries (Australia, Singapore, and Turkey). Students in their fourth year of undergraduate courses (n = 922; 30.3%) were represented in ten studies conducted in Canada, Portugal, United States of America, South Korea, and Jordan. Most studies did not provide descriptive statistics related to gender.

Interventions and comparisons

Studies utilized a variety of both HFPS (intervention group) and other teaching methods (control group). Most of simulators utilized in the intervention groups by qualified instructors or tutors were Laerdal (n = 16; 47.1%). Simulation sessions were based mainly on cardio-circulatory scenarios (n = 30; 54.5%), followed by

respiratory scenarios (n = 16; 29.1%) and others (n = 9; 16.4%). Among the control group interventions, more than one third utilized lectures (n = 14; 31.1%), no intervention (n = 11; 24.4%), or low-fidelity manikin (n = 5; 11.1%).

Outcome measures

The subjective outcomes (satisfaction, self-confidence, and self-efficacy) were measured by self-rating instruments (e.g. Resuscitation Self-Efficacy Scale, Satisfaction with Clinical Experience Simulation Scale, etc.), whereas the objective outcomes (knowledge and performance) through direct observation of performance by raters or other objective instruments (e.g. ACLS Mega Code Performance Score Sheet, ACLS Written Examination, etc.), as shown in Table C (supplementary file). Different types of measurement tools were detected including Likert-type scales (n = 25 43.9%), multiple-choice questionnaires (n = 11; 19.3%), dichotomous scales (n = 7; 12.3%), checklists (n = 3; 5.3%), open questions (n = 1; 1.7%), and others (n = 10; 17.5%).

Type of studies

Most studies included in this meta-analysis were based on a quasi-experimental design with a pseudo-randomized allocation to groups (n = 29; 87.9%) while the remaining studies (n = 4; 12.1%) were randomized controlled trials. The included studies were published from 2006 to 2017 and their design features and extracted data are available for consultation in the Table D and Table C of the supplementary file.

Quality appraisal of individual studies

Good internal validity was reported for all included studies (Table E of the supplementary file), while 42.4% of the studies (n = 14) demonstrated good external validity, and just over half (n = 19) depicted a scarce generalizability of the results mainly due to lack of details concerning the process of recruiting participants (57.6%).

Results of individual studies and synthesis of results

HFPS sessions showed significant larger effects sizes for knowledge (d = 0.49, 95% CI [0.17; 0.81], Z-test = 3.06, p = 0.003) and performance (d = 0.50, 95% CI [0.19; 0.81], Z-test = 3.12, p = 0.001) than any other teaching method (Figure 2 and 3). No significant differences were detected between HFPS and control groups for the satisfaction (d = 0.38, 95% CI [-0.01; 0.77], Z-test = 1.90, p = 0.053), self-confidence (d = 0.21, 95% CI [-0.02; 0.43], Z-test = 1.75, p = 0.072), and self-efficacy (d = 0.05, 95% CI [-0.45; 0.55], Z-test = 0.20, p = 0.840) (Figure 4, 5, and 6).

Since Q-test highlighted a significant heterogeneity ($p \leq 0.01$) for all the outcomes (I^2 from 70.09% to 89.85%), subgroup analyses were carried out to determine its source (Table 1). The scenario (ANOVA Q-test 11.43, p = 0.003), manikin brand (ANOVA Q-test 10.59, p = 0.001), and control intervention (ANOVA Q-test 13.37, p = 0.010) appeared to be the source of heterogeneity for self-efficacy. Otherwise, these moderators did not prove to be the sources of heterogeneity for the remaining learning outcomes.

Table 1. Nursing students' learning outcomes subgroup analyses

Moderators	Categories	Knowledge Q=79.16 I^2=84.84% $p\leq0.01$	Performance Q=122.54 I^2=83.68% $p\leq0.01$	Satisfaction Q=118.24 I^2=89.85% $p\leq0.01$	Self-confidence Q=76.58 I^2=79.11% $p\leq0.01$	Self-efficacy Q=13.37 I^2=70.09% $p\leq0.01$

		Q	I^2	Sig.	Q	I^2	Sig.	Q	I^2	Sig.	Q	I^2	Sig.	Q	I^2	Sig.
Scenario	Cardio-circulatory	63.38	90.53	**<0.001**	82.99	85.54	**<0.001**	6.67	40.07	0.154	18.87	73.51	**0.002**	0.83	0.00	0.362
	Respiratory	8.81	65.95	**<0.001**	19.65	79.65	**0.001**	111.41	93.72	**<0.001**	29.23	79.47	**<0.001**	1.12	10.47	0.291
	Other	2.76	63.76	0.097	10.18	80.35	**<0.001**	-	-	-	28.33	85.88	**<0.001**	-	-	-
Manikin brand	Laerdal®	3.47	0.00	0.482	59.94	86.65	**<0.001**	24.49	83.67	**<0.001**	5.43	26.38	0.246	0.83	0.00	0.362
	Med Sim Eagle	-	-	-	-	-	-	na	na	na	-	-	-	-	-	-
	METI™	30.02	93.34	**<0.001**	48.13	87.53	**<0.001**	-	-	-	24.22	87.61	**<0.001**	-	-	-
	Unspecified	22.97	82.58	**<0.001**	3.63	0.00	0.458	89.84	93.32	**<0.001**	47.47	83.15	**<0.001**	1.95	0.00	0.377
Control intervention	Audio-listening	-	-	-	1.72	41.96	0.189	-	-	-	na	na	na	-	-	-
	Lecture	53.54	94.40	**<0.001**	20.00	85.00	**<0.001**	15.32	73.89	**0.004**	23.83	74.82	**0.001**	na	na	na
	Low-fidelity manikin	16.42	87.82	**<0.001**	4.74	57.82	0.093	-	-	-	na	na	na	-	-	-
	Medium-fidelity manikin	na	na	na	-	-	-	3.94	49.19	0.140	0.40	0.00	0.528	na	na	na
	No intervention	0.36	0.00	0.548	48.75	87.69	**<0.001**	-	-	-	8.14	63.16	**0.043**	na	na	na
	Problem-based learning	na	na	na	3.39	70.47	0.066	na	na	na	na	na	na	-	-	-
	Role-playing	-	-	-	na	na	na	na	na	na	na	na	na	na	na	na
	Standardized patient	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Video-watching	-	-	-	na	na	na	-	-	-	-	-	-	-	-	-
	Web-based learning	na	na	na	-	-	-	2.15	53.46	0.143	-	-	-	-	-	-

Note: not applicable for number of studies = 1 (na); no studies (-)

Sensitivity analysis

In regards to the objective outcomes, such as knowledge and performance, the strength of the pooled effect sizes was still robust and significant (ranging from 0.38 to 0.58 and from 0.43 to 0.57, respectively) and did not significantly differ according to the characteristics of individual studies in the leave-one-out sensitivity analysis.

Regarding the self-rating outcome of satisfaction, the pooled effect size became significant by removing Kang 2015a, Luctkar-Flude 2012a, or Luctkar-Flude 2012b (0.51, p = 0.002; 0.48, p = 0.018; 0.42, p = 0.047; respectively). Even about the self-confidence, the pooled effect size became significant when Ahn 2015b, Brannan 2008, Kang 2015a, Luctkar-Flude 2012a, or Luctkar-Flude 2012b were removed (all 0.25, p-value from 0.027 to 0.032). The last self-rating outcome, i.e. self-efficacy, did not show any change of the effect size that remained not significant in all cases (ranging from -0.13 to 0.26).

Risk of bias

With the exception of self-efficacy, no significant publication biases were detected on performed tests measuring knowledge, performance, satisfaction, and self-confidence. For self-efficacy the Egger's regression showed a significant risk of publication bias (intercept = -6.54, p = 0.018), even if no change in the effect size was found by the Trim and Fill method between the observed and estimated values (d = 0.05, 95% CI -0.45 to 0.55), as shown in Figure 2 of the supplementary file. The Fail-safe number was 0.

DISCUSSION

Study characteristics

In this review, a significant increase in HFPS research based on life-threatening clinical condition scenarios was detected over the years, which recognizes simulation-based education as a key component of nursing education [41 42] especially for life-threatening clinical conditions requiring rapid and effective interventions. Although a positive publication trend on this topic emerged, most of the research had been conducted in North America. Consequently, generalizability of results in Europe and Asia is limited given the differences in many academic and curriculum aspects.[43]

In accordance with global health concerns,[44-46] life-threatening clinical condition scenarios utilized in HFPS sessions were mainly based on cardio-circulatory and respiratory clinical problems that allowed

students to manage high risk situations rarely practically faced during their clinical training.[11] In this regard, to comprehend if patients will receive better and safer care due to the improvement on learning outcomes in nursing students produced by HFPS, translational research on this topic should be strengthened. Given the emerging variety of measurement tools (e.g. Likert-type, multiple-choice, etc.), research methods on this topic should be more focused and rigorous. In particular, *ad hoc* scenario-specific instruments with reported reliability and validity should meet the minimum general requirements of global shared guidelines in order to have comparable results [47]. Standardization of their core contents is strongly advisable. [20 48] Considering these issues, this meta-analysis should be read cautiously considering that few included studies had a good external validity and adopted a randomized controlled design. Therefore, conducting high-quality replication studies on this topic is recommended.

HFPS and nursing students' learning outcomes

This systematic review analysed the effectiveness of HFPS utilizing life-threatening clinical condition scenarios on nursing students' learning outcomes. In accordance with other reviews conducted on this topic,[18 24 25] although with different aims and populations, HFPS seems to improve students' knowledge [19 34 36 40 49-56] and performance [34 52 57-68], that are considered objective outcomes in current literature. [69] Considering that competence can be defined as knowledge and performance combined with psychomotor and clinical problem-solving skills,[70] HFPS can be considered an important teaching method that can contribute to build nursing competence especially in the area of critical care. Engaging in simulated life-threatening clinical condition scenarios, students could improve their ability to provide appropriate and safe nursing care in patients with unstable and rapidly changing clinical conditions. However, it is not enough for nursing students to just demonstrate good knowledge and performance to completely achieve their learning outcomes as well as securely meet the needs of the critically-ill patient.

In regards to subjective outcomes, [69] nursing is an aid profession and patients need to feel safe and reassured, therefore, adequate levels of self-confidence and self-efficacy [30] are required in order to improve the well-being of nurses that is closely linked to the quality of care provided. However, this review does not confirm the benefits of HFPS based on life-threatening clinical condition scenarios in improving nursing students' self-efficacy,[66 67 71 72] self-confidence,[50 51 53 56 57 60 66 67 71 73-78] and satisfaction.[49-51 66 75 77 79-82] Maybe, non-significant results for these learning outcomes are due not only to the small sample sizes of some included studies but also to the outcome measurement performed immediately after any single simulation experience, not allowing the detection of any change. To achieve significant improvements in self-efficacy and self-confidence, it may be useful to provide students with repeated exposures to the HFPS sessions in order to maintain successful performances over time and allow them to observe the success of the other students to increase encouragement and engagement.[30 83 84] Hence, future studies should utilize repeated exposures to the HFPS with outcome evaluation during both intermediate- and long-term intervals. The increased use of HFPS in nursing education programs may result in more clinically confident and proficient nurses who are able to respond accurately and appropriately to

patients' needs.[85] To better understand how the gain in performance and knowledge improves patient outcomes, more research based on translational approach is required.[48]

The results from this meta-analysis were affected by a high heterogeneity and was not explained by those variables except for self-efficacy, and was likely due to the different application methods of HFPS across several context of the studies. Unfortunately, most studies did not provide data useful to exploring the reasons for the heterogeneity that represents both a threat to the reliability of the results [86] and an opportunity to provide a quantitative proof of the methodological limitations in the current research.

The unexplained heterogeneity detected from this meta-analysis have a surprising usefulness in orienting future research to provide evidence-based responses to various unsolved questions related to the ability of HFPS to improve nursing learning outcomes. Further details are needed in regards to how long should a simulation session last? What are the best briefing and debriefing methods? What are the most effective facilitation methods to use during the simulation? What is the ideal number of participants in each session? Even if many studies have been conducted in these fields and also there are standards of best practice in simulation [12 17 25 47], the results of this meta-analysis highlighted that a high heterogeneity in simulation practice and research persists. [87] Therefore, further studies utilizing shared HFPS practice and investigation methods are needed to achieve more homogeneity in literature in order to allow the establishment of evidence-based guidelines, protocols, and algorithms [88 89] that interrupt the vicious circle in which the lack of homogeneity in the behaviors determines a heterogeneity of the results and vice versa.

Limitations

This systematic review analysed the effectiveness of HFPS through life-threatening clinical condition scenarios on nursing students learning outcomes. The robustness of results was confirmed for knowledge, performance, and self-efficacy after sensitivity analysis; however, some limitations were revealed.

Even if a good internal validity was reported for all the included studies, only few researches were based on an experimental design. Consequently, as likely and unmeasurable confounding and selection bias could be present in no experimental included studies, the results of this meta-analysis should be cautiously considered also in the light of the relevant heterogeneity. In addition, the basic knowledge of postgraduate students hypothetically higher than undergraduate students could have potentially affected the effect size of the considered outcomes. Publication bias detected for self-efficacy was probably due to negative studies less likely to be published or to a more attention paid by editors to manuscripts investigating objective than self-rating outcomes; consequently, caution in the interpretation of the results is necessary. Finally, lack of data about the participants' characteristics, measurement tools, duration of the session, and briefing and debriefing modalities limit the analyses and interpretation of the results.

Conclusions

Results of this systematic review demonstrate HFPS is superior to other teaching methods in improving knowledge and performance of nursing students when exposed to life-threatening clinical condition scenarios, corroborating the importance of HFPS into the academic educational programs especially for the management of clinically acute events. However, more studies are still necessary to explore the potential use

of the HFPS as an effective tool to increase nursing students' competence levels and to better understand its impact on patient outcomes.

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Competing interests

None declared.

Contributors

All authors developed the protocol, interpreted the results, and approved the final version. CLC, AD, IF, EG, and VC completed the search, screened articles for inclusion, and synthesised the findings. CLC and AD extracted data and drafted the manuscript. CP, CA, and LL critically revised the manuscript.

Patient consent

Not required.

Data sharing statement

There are no unpublished data for this review.

Figure 1. Search and selection strategy PRISMA flow-chart

Figure 2. Effect of HFPS on nursing students' knowledge

Figure 3. Effect of HFPS on nursing students' performance

Figure 4. Effect of HFPS on nursing students' satisfaction

Figure 5. Effect of HFPS on nursing students' self-confidence

Figure 6. Effect of HFPS on nursing students' self-efficacy

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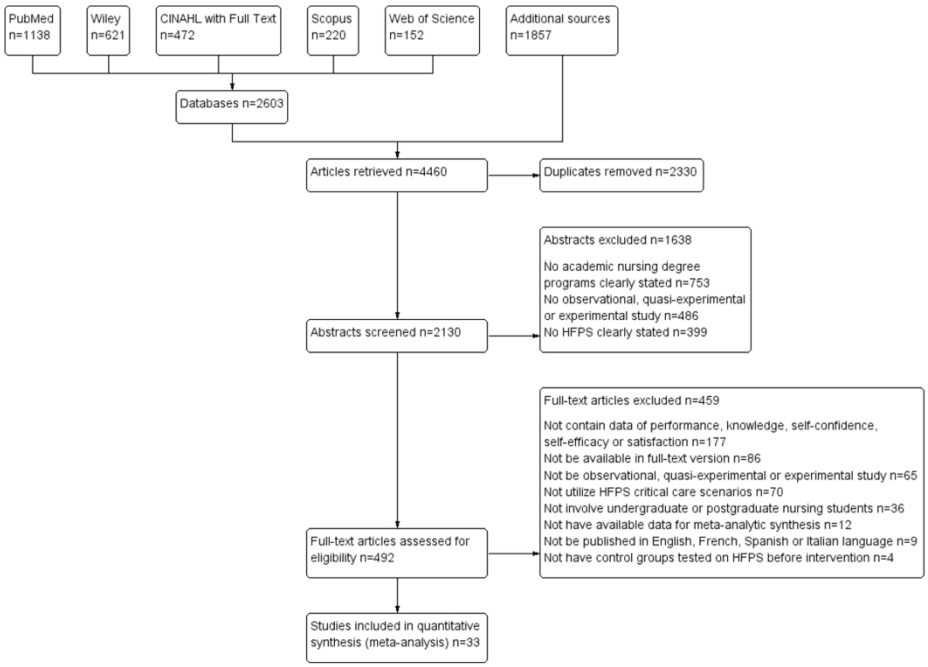

Figure 1. Search and selection strategy PRISMA flow-chart

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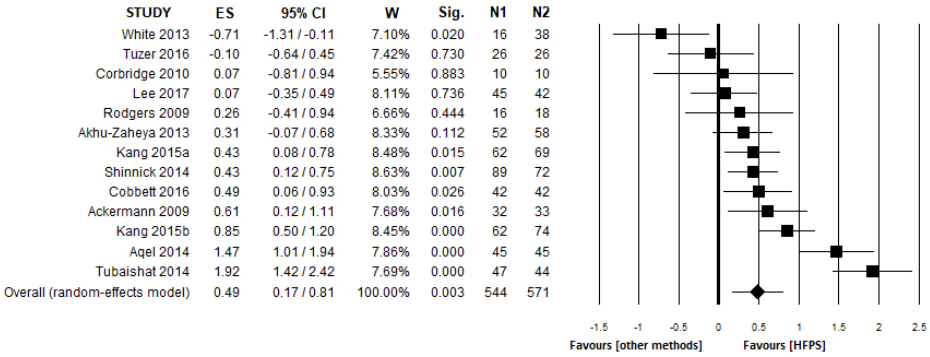

Figure 2. Effect of HFPS on nursing students' knowledge

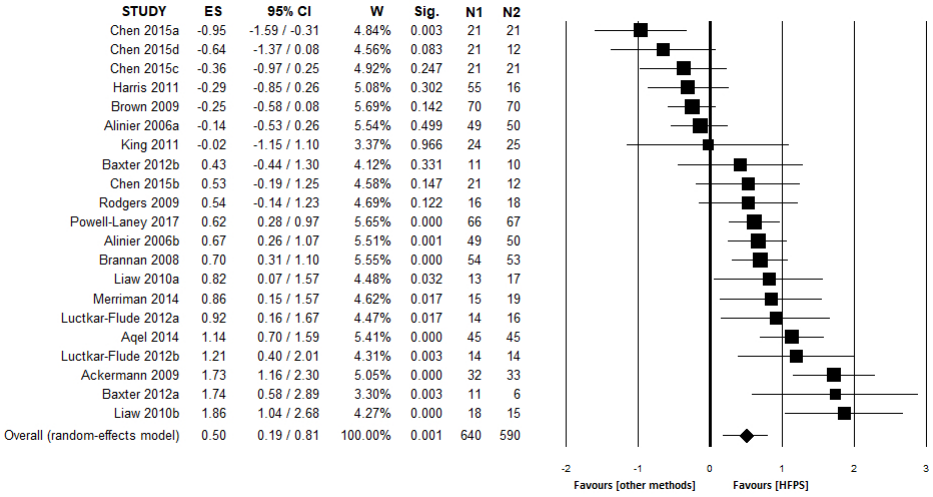

Figure 3. Effect of HFPS on nursing students' performance

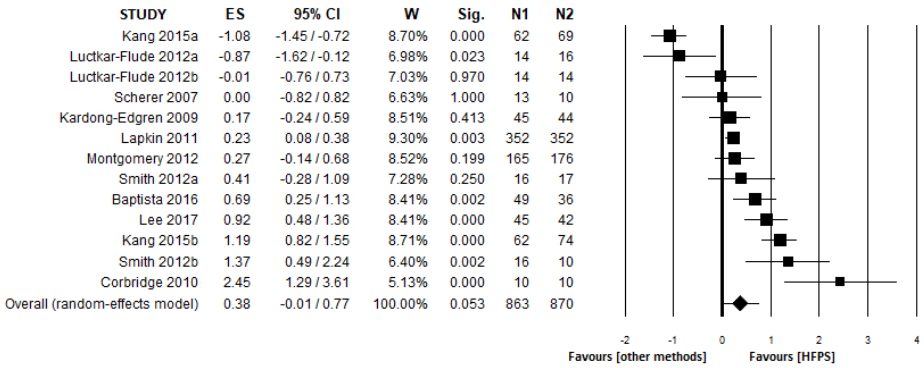

Figure 4. Effect of HFPS on nursing students' satisfaction

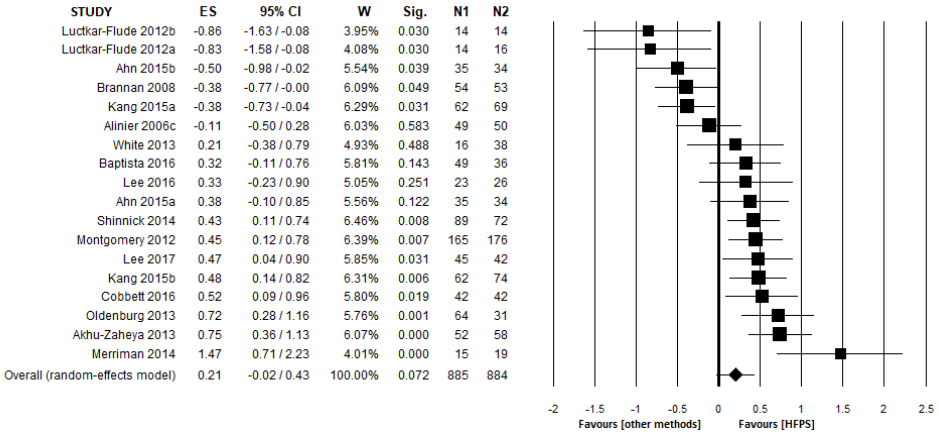

Figure 5. Effect of HFPS on nursing students' self-confidence

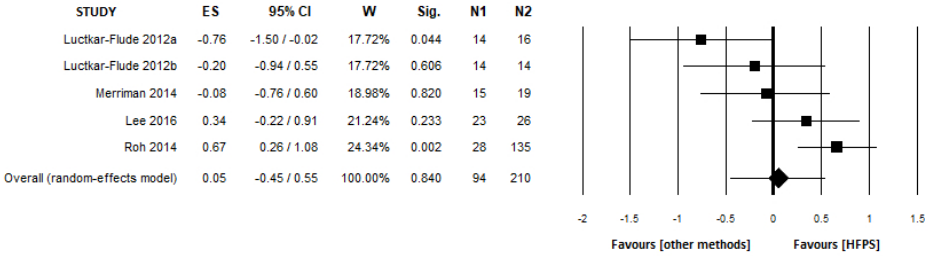

Figure 6. Effect of HFPS on nursing students' self-efficacy

Supplementary file

Box - Complete search strategy

PubMed

1. exp Education, nursing/
2. nurs$.ti,ab.
3. educat$.ti,ab.
4. 2 and 3
5. “nursing degree course”.ti,ab.
6. student$.ti,ab.
7. 2 and 6
8. exp Students, nursing/
9. "teaching and learning model".ti,ab.
10. 2 and 9
11. exp Teaching/
12. 2 and 11
13. 1 or 4 or 5 or 7 or 8 or 10 or 12
14. "acute care".ti,ab.
15. AED.ti,ab.
16. exp Airway management/
17. exp Cardiovascular diseases/
18. CPR.ti,ab.
19. exp Critical care/
20. exp Critical care nursing/
21. exp Life support care/
22. defibrillat$.ti,ab.
23. exp Defibrillators/
24. exp Electrocardiography/
25. ECG.ti,ab.
26. exp Electric countershock/
27. electrocardio$.ti,ab.
28. exp Emergencies/
29. exp Emergencies nursing/
30. exp Emergency medical service/
31. exp Emergency treatment/
32. exp Hemodynamics/
33. exp Monitoring, physiologic/
34. "patient deterioration”.ti,ab.
35. exp Respiration disorders/
36. exp Respiration, therapy/
37. 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 or 35 or 36
38. fidelity.ti,ab.
39. “human patient”.ti,ab.
40. mannequin$.ti,ab.
41. exp Program development/
42. scenario$.ti,ab.
43. “simulated patient$”.ti,ab.
44. “simulation-based training".ti,ab.
45. 38 or 39 or 40 or 41 or 42 or 43 or 44
46. exp Mental processes/
47. $confiden$.ti,ab.
48. exp Clinical decision-making/
49. debrief$.ti,ab.
50. exp Educational measurement/
51. "fitness to practice".ti,ab.
52. gain$.ti,ab.
53. exp Health knowledge, attitudes, practice/
54. exp Needs assessment/
55. "objective structured clinical examination".ti,ab.
56. OSCE.ti,ab.
57. perceive$.ti,ab.
58. perception$.ti,ab.
59. performance$.ti,ab.
60. exp Personal satisfaction/

61. "physical assessment".ti,ab.
62. exp Psychomotor performance/
63. exp Aptitude tests/
64. retention$.ti,ab.
65. retain$.ti,ab.
66. satisfact$.ti,ab.
67. exp Self concept/
68. aware$.ti,ab.
69. efficac$.ti,ab.
70. skill$.ti,ab.
71. 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70
72. 13 and 37 and 45 and 71
73. limit 72 to (article type="Comparative Study", "Journal Article", "Observational Study". "Clinical Trial", "Controlled Clinical Trial", "Randomized Trial") and (publication date to "2017/05/31")

Scopus

TITLE-ABS-KEY (((nurs* AND educat*) OR "nursing degree course" OR (nurs* AND student*) OR ("teaching and learning model" AND nurs*)) AND ("acute care" OR aed OR cpr OR defibrillat* OR ecg OR electrocardio* OR "patient deterioration") AND (simulat* OR fidelity OR "human patient" OR manikin* OR mannequin* OR scenario*) AND (*confiden* OR debrief* OR "fitness to practice" OR gain* OR "objective structured clinical examination" OR osce OR perceive* OR perception* OR performance* OR "physical assessment" OR retention* OR retain* OR satisfact* OR aware* OR efficac* OR skill*)) [Article types: Article, Article in Press]

CINAHL with Full Text

S71 limit S70 to (document type="academic publication", "journals", "CEU"), ("research article"), (year="1900.01.01"-"2017.05.31") and expand to ("search also in full text")
S70 S12 and S35 and S43 and S69
S69 or/S44-S68
S68 (MH “Mental Processes”)
S67 AB (skill*)
S66 AB (efficac*)
S65 AB (aware*)
S64 (MH "Self Concept+")
S63 AB (satisfact*)
S62 AB (retain*)
S61 AB (retention*)
S60 (MH “Aptitude Tests”)
S59 (MH "Psychomotor Performance+")
S58 AB ("physical assessment")
S57 (MH "Student Satisfaction+")
S56 AB (performance*)
S55 AB (perception*)
S54 AB (perceive*)
S53 (MH "Student Performance Appraisal+")
S52 AB (OSCE)
S51 AB ("objective structured clinical examination")
S50 (MH "Needs Assessment")
S49 (MH "Health Knowledge")
S48 AB (gain*)
S47 AB ("fitness to practice")
S46 (MH "Educational Measurement+")
S45 AB (debrief*)
S44 AB (*confiden*)
S43 or/S36-S42
S42 (MH "Program Development+")
S41 (MH "Problem-Based Learning")
S40 AB (mannequin*)
S39 AB (manikin*)
S38 (MH "Learning Environment+")
S37 AB ("human patient")
S36 AB (fidelity)
S35 or/S13-S34
S34 (MH "Respiration Therapy+")
S33 (MH "Respiration Disorders+")

S32 AB ("patient deterioration")
S31 (MH "Monitoring, Physiologic+")
S30 (MH "Hemodynamics+")
S29 AB (electrocardio*)
S28 AB (ECG)
S27 (MH "Defibrillation")
S26 (MH "Defibrillators+")
S25 AB (defibrillat*)
S24 (MH "Life Support Care+")
S23 (MH "Critical Care Nursing+")
S22 (MH "Emergency Treatment+")
S21 (MH "Emergency Medical Service+")
S20 (MH "Emergency Care+")
S19 (MH "Emergencies+")
S18 (MH "Critical Care+")
S17 AB (CPR)
S16 (MH "Cardiovascular Diseases+")
S15 (MH "Airway Management+")
S14 AB (AED)
S13 AB ("acute care")
S12 or/S1-S8 or S11
S11 S9 and S10
S10 AB (nurs*)
S9 (MH "Teaching+")
S8 AB ("teaching and learning model" and nurs*)
S7 (MH "Students, Nursing+")
S6 AB (nurs* and student*)
S5 AB ("nursing degree course")
S4 AB (nurs* and educat*)
S3 (MH "Emergency Nursing+")
S2 (MH "Education, Nursing+")
S1 (MH "Education, Competency-Based+")

Wiley Online Library

(nurs* AND educat*) OR "nurse faculty" OR "nursing degree course" OR (nurs* AND student") OR ("teaching and learning model" AND nurs*) in Abstract AND ("acute care" OR AED OR CPR OR defibrillat* OR ECG OR electrocardio* OR "patient deterioration") in FullText AND (simulat* OR fidelity OR "human patient" OR manikin* OR mannequin* OR scenario*) in Abstract AND (*confiden* OR debrief* OR "fitness to practice" OR gain* OR "objective structured clinical examination" OR OSCE OR perceive* OR perception* OR performance* OR "physical assessment" OR retention* OR retain* OR satisfact* OR aware* OR efficac* OR skill*) in FullText [Publication Type: Journals]

Web of Science

TS=(((nurs* AND educat*) OR "nursing degree course" OR (nurs* AND student*) OR ("teaching and learning model" AND nurs*)) AND ("acute care" OR AED OR CPR OR defibrillat* OR ECG OR electrocardio* OR "patient deterioration") AND (simulat* OR fidelity OR "human patient" OR manikin* OR mannequin* OR scenario*) AND (*confiden* OR debrief* OR "fitness to practice" OR gain* OR "objective structured clinical examination" OR OSCE OR perceive* OR perception* OR performance* OR "physical assessment" OR retention* OR retain* OR satisfact* OR aware* OR efficac* OR skill*)) [All years, Document Types: Article]

Table A - NICE Quality Appraisal Checklist for Quantitative Intervention Studies

SECTION 1: POPULATION
1.1 Is the source population or source area well described? Was the country, setting, location (urban, rural), population demographics etc. adequately described?
1.2 Is the eligible population representative of the source population? Was the recruitment well defined? Was the population representative of the source?
1.3 Do the selected participants or areas represent the eligible population or area? Was the method of selection of participants from the eligible population well described? What % of selected individuals or clusters agreed to participate? Were there any sources of bias? Were the inclusion or exclusion criteria explicit and appropriate?
SECTION 2: METHOD OF ALLOCATION TO INTERVENTION (OR COMPARISON)
2.1 Allocation to intervention (or comparison). How was selection bias minimised? Was allocation to exposure and comparison randomised? Was it truly random ++ or pseudo-randomised + (e.g. consecutive admissions)? If not randomised, was significant confounding likely (−) or not (+)? If a cross-over, was order of intervention randomised?
2.2 Were interventions (and comparisons) well described and appropriate? Were interventions and comparisons described in sufficient detail? Were comparisons appropriate?
2.3 Was the allocation concealed? Adequate allocation concealment (++) would include centralised allocation or computerised allocation systems.
2.4 Were participants or investigators blind to exposure and comparison? Were those delivering or assessing the intervention kept blind to intervention allocation? (Triple or double blinding score ++). If lack of blinding is likely to cause important bias, score −.
2.5 Was the exposure to the intervention and comparison adequate? Is reduced exposure to intervention or control related to the intervention or fidelity of implementation?
2.6 Was contamination acceptably low? Did any in the comparison group receive the intervention or vice versa? If so, was it sufficient to cause important bias? If a cross-over trial, was there a sufficient wash-out period between interventions?
2.7 Were other interventions similar in both groups? Did either group receive additional interventions or have services provided in a different manner? Were the groups treated equally by researchers or other professionals? Was this sufficient to cause important bias?
2.8 Were all participants accounted for at study conclusion? Were those lost-to-follow-up <20%? Did the proportion dropped differ by group?
2.9 Did the setting reflect usual practice? Did the setting in which the intervention or comparison was delivered differ significantly from usual practice? For example, did participants receive intervention (or comparison) condition in a hospital rather than a community-based setting?
2.10 Did the intervention or control comparison reflect usual practice? Did the intervention or comparison differ significantly from usual practice?
SECTION 3: OUTCOMES
3.1 Were outcome measures reliable? Were outcome measures subjective or objective? How reliable were measures? Was there any indication that measures had been validated?
3.2 Were all outcome measurements complete? Were all or most study participants who met the defined study outcome definitions likely to have been identified?
3.3 Were all important outcomes assessed? Were all important benefits and harms assessed? Was it possible to determine the overall balance of benefits and harms?
3.4 Were outcomes relevant? Where surrogate outcome measures were used, did they measure what they set out to measure?
3.5 Were there similar follow-up times in exposure and comparison groups? If groups are followed for different lengths of time, then more events are likely to occur in the group followed-up for longer distorting the comparison. Analyses can be adjusted to allow for differences in length of follow-up.
3.6 Was follow-up time meaningful? Was follow-up long enough to assess long-term benefits or harms? Was it too long, e.g. participants lost to follow-up?
SECTION 4: ANALYSES
4.1 Were groups similar at baseline? If not, were these adjusted? If so, were these adjusted for in the analyses (e.g. multivariate analyses or stratification)
4.2 Was intention to treat analysis conducted? Were all participants (including dropped out or did not complete the intervention) analysed?
4.3 Was the study sufficiently powered to detect an intervention effect? A power of 0.8 is the conventional standard. Is a power calculation presented?
4.4 Were the estimates of effect size given or calculable? Were effect estimates (e.g. relative risks, absolute risks) given or possible to calculate?
4.5 Were the analytical methods appropriate? Were important differences in follow-up time and likely confounders adjusted for? Were subgroup analyses pre-specified?
4.6 Was the precision of intervention effects given or calculable? Were they meaningful? Were CIs or p values for effect estimates given or possible to calculate?

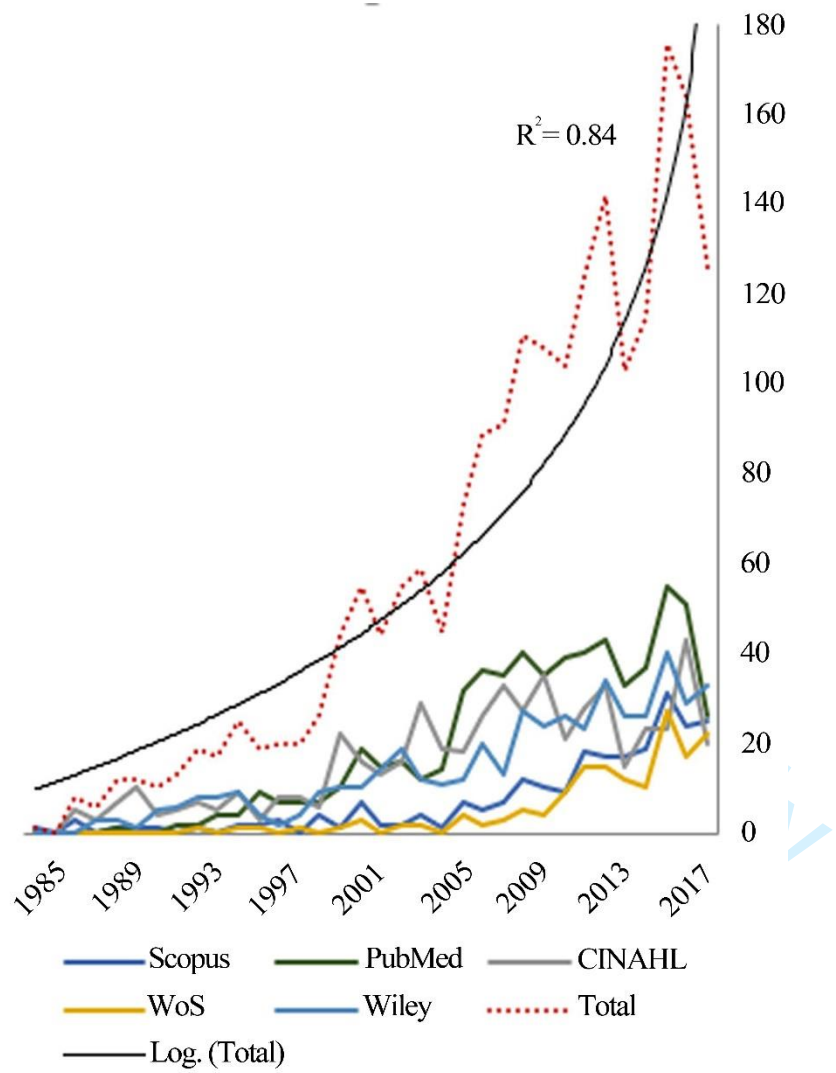

Figure 1 - HFPS Publication trend

Table B - Description of included studies (n = 33; k = 44)

n	k	First Author	Title	IF	Country	Aim	Students enrolled	N	Year	Age M (SD)	Females N (%)
1	1	Ackermann 2009	Investigation of learning outcomes for the acquisition and retention of CPR knowledge and skills learned with the use of high-fidelity simulation	1.277	USA	To investigate the impact of variables such as accelerated versus traditional nursing students and the experience with CPR on a living person.	Undergraduate (Baccalaureate)	65	1st	nd	nd
2a **2b**	2 3	Ahn 2015	Implementation and outcome evaluation of high-fidelity simulation scenarios to integrate cognitive and psychomotor skills for Korean nursing students.	2.533	South Korea	To implement two high-fidelity simulations to help nursing students integrate their cognitive and psychomotor skills.	Undergraduate (Bachelor)	69	3rd	IG 20.1 (1.2) CG 20.8 (2.7)	IG 32 (91.4) CG 32 (94.1) All 64 (92.8)
3	4	Akhu-Zaheya 2013	Effectiveness of simulation on knowledge acquisition, knowledge retention, and self-efficacy of nursing students in Jordan	1.277	Jordan	To examine the effect of high-fidelity BLS simulation on knowledge acquisition, knowledge retention, and self-efficacy of Jordanian nursing students	Undergraduate (Bachelor)	110	2nd	20.0 (0.6)	74 (67.0)
4a **4b** **4c**	5 6 7	Alinier 2006	Effectiveness of intermediate-fidelity simulation training technology in undergraduate nursing education.	1.998	UK	To determine the effect of scenario-based simulation training on nursing students' clinical skills and competence.	Postgraduate (Diploma)	99	2nd	IG 29.3 (7.5) CG 33.0 (8.4) All 31.2 (8.2)	IG 42 (85.7) CG 41 (82.0) All 83 (83.8)
5	8	Aqel 2014	High-Fidelity Simulation Effects on CPR Knowledge, Skills, Acquisition, and Retention in Nursing Students.	2.103	Jordan	To examine the effect of using high-fidelity simulators on knowledge and skills acquisition and retention with university students.	Undergraduate (Baccalaureate)	90	2nd	19.9 (1.8)	71 (78.9)
6	9	Baptista 2016	Satisfaction and gains perceived by nursing students with medium and high-fidelity simulation: A randomized controlled trial.	2.533	Portugal	To analyze and benchmark gains and satisfaction perceived by nursing students, according to their participation in medium- and high-fidelity simulated practice.	Undergraduate (Bachelor)	85	4th	21.9 (2.8)	IG 44 (49.8) CG 35 (97.2) All 79 (92.9)
7a **7b**	10 11	Baxter 2012	Teaching Critical Management Skills to Senior Nursing Students: Videotaped or Interactive Hands-On Instruction?	0.91	Canada	To examine and compare the effectiveness of videotape training versus hands-on instruction in preparing senior nursing students to respond to emergency clinical situations.	Undergraduate (Bachelor)	17 (a) 21 (b)	4th	nd	nd
8	12	Brannan 2008	Simulator effects on cognitive skills and confidence levels.	1.28	USA	To compare the effects of two instructional methods to teach specific nursing education content on junior-level nursing students' cognitive skills and confidence.	Undergraduate (Baccalaureate)	107	1st	IG 28.6 (8.4) CG 28.3 (7.2)	IG 50 (93.0) CG 51 (96.0) All 101 (79.5)
9	13	Brown 2009	The effect of simulation learning on critical thinking and self-confidence when incorporated into an electrocardiogram nursing course	1.277	USA	To demonstrate the effect of simulation activities on critical thinking and self-confidence in an electrocardiogram nursing course	Undergraduate (Baccalaureate)	140	4th	IG 28.0 (nd) CG 26.7 (nd) All 27.5 (nd)	IG 62 (89.0) CG 62 (89.0) All 62 (89.0)
10a **10b** **10c** **10d**	14 15 16 17	Chen 2015	Evaluating the impact of high-and low-fidelity instruction in the development of auscultation skills.	4.005	Canada	To explore the effectiveness of HF and low-fidelity instruction on tasks that are chosen to deliberately test skills close to, and more removed from, the clinical environment, within the clinical domains of cardiac and respiratory auscultation and physical assessment skill development.	Undergraduate (Bachelor)	42 (a) 33 (b) 42 (c) 33 (d)	3rd	nd	nd
11	18	Cobbett 2016	Virtual versus face-to-face clinical simulation in relation to student knowledge, anxiety, and self-confidence in maternal-newborn nursing: A randomized controlled trial.	2.533	Canada	To compare the effectiveness of two maternal newborn clinical simulation scenarios; virtual clinical simulation and face-to-face high-fidelity manikin simulation.	Undergraduate (Bachelor)	84	3rd	25.0 (nd)	47 (84.0)
12	19	Corbridge 2010	Online learning versus simulation for teaching principles of mechanical ventilation to nurse practitioner students.	1.04	USA	To determine differences in knowledge acquisition and student satisfaction between two methods of teaching mechanical ventilation to advanced practice nursing (APN) students: high-fidelity patient simulation versus an online, narrated PowerPoint presentation.	Postgraduate (Advanced Practice Nursing)	20	na	IG 34.5 (10.1) CG 39.2 (9.9)	nd
13	20	Harris 2011	Simulation-enhanced pediatric clinical orientation.	1.28	USA	To determine the effect of simulation-enhanced orientation on pediatric acute care examination scores and pediatric clinical course grades among junior-level baccalaureate nursing students.	Undergraduate (Baccalaureate)	71	1st	nd	nd
14a **14b**	21 22	Kang 2015	Comparison of knowledge, confidence in skill performance (CSP) and satisfaction in problem-based learning (PBL) and simulation with PBL educational modalities in caring for children with bronchiolitis.	2.533	South Korea	To compare changes in nursing students' knowledge, confidence in skill performance (CSP), and satisfaction resulting from training using three educational modalities.	Undergraduate (Bachelor)	131(a) 136 (b)	4th	nd	nd
15	23	Kardong-Edgren 2009	VitalSim® versus SimMan®: A comparison of BSN student test scores, knowledge retention, and satisfaction.	1,277	USA	To verify if student satisfaction and knowledge gains are equivalent with a medium-fidelity simulator such as VitalSim® and a high-fidelity simulator such as SimMan®, and if they provide more overall student and program access to simulation.	Undergraduate (Bachelor)	89	1st	nd	nd
16	24	King 2011	Teaching advanced cardiac life support protocols	1.372	USA	To compare the effectiveness of static simulation to high-fidelity simulation when teaching advanced cardiac life support guidelines	Undergraduate (Bachelor)	49	4th	nd	nd
17	25	Lapkin 2011	A cost–utility analysis of medium vs. high-fidelity human patient simulation manikins in nursing education.	1.214	Australia	To determine whether the extra costs associated with high-fidelity manikins can justify the differences, if any, in the outcomes of clinical reasoning, knowledge acquisition and student satisfaction.	Undergraduate (Bachelor)	352	2nd (268) 3rd (84)	nd	299 (85.0)
18	26	Lee 2016	Effects of high-fidelity patient simulation led clinical reasoning course: Focused on nursing core competencies, problem solving, and academic self-efficacy.	0.554	South Korea	To examine effects of high-fidelity patient simulation (HFPS) led clinical reasoning course among undergraduate nursing students.	Undergraduate (Bachelor)	49	4th	nd	nd

19	27	Lee 2017	Effects of pre-education combined with a simulation for caring for children with croup on senior nursing students.	1.17	South Korea	Educational outcomes were compared between groups that received education through simulation combined with pre-education, simulation alone, and preeducation alone.	Undergraduate (Bachelor)	87	4th	nd	nd
20a 20b	28 29	Liaw 2010	Developing clinical competency in crisis event management: An integrated simulation problem-based learning activity.	1.06	Singapore	To evaluate the integration of a simulation-based learning activity on nursing students' clinical crisis management performance in a problem-based learning (PBL) curriculum.	Undergraduate (Baccalaureate)	30 (a) 33 (b)	1st	20.0 (1.0)	nd
21a 21b	30 31	Luctkar-Flude 2012	Evaluating high-fidelity human simulators and standardized patients in an undergraduate nursing health assessment course.	2.533	Canada	To investigate learners' satisfaction, self-efficacy and performance behaviors among high-fidelity human simulators (HFPS), standardized patients (SP) and community volunteers (CV).	Undergraduate (Bachelor)	30 (a) 28 (b)	2nd	nd	nd
22	32	Merriman 2014	Comparing the effectiveness of clinical simulation versus didactic methods to teach undergraduate adult nursing students to recognize and assess the deteriorating patient.	1.277	UK	To evaluate the effectiveness of clinical simulation compared to classroom teaching in the assessment of the deteriorating patient.	Undergraduate (Bachelor)	34	1st	nd	nd
23	33	Montgomery 2012	Student satisfaction and self-report of CPR competency: Heart-Code™ BLS courses, instructor-led CPR courses, and monthly voice advisory manikin practice for CPR skill maintenance	1.04	USA	To evaluate the effects of brief monthly refresher training on CPR skill retention, confidence, and satisfaction with CPR skill level of nursing students.	Undergraduate (Baccalaureate) Postgraduate (Diploma, Associate)	341	1st na	nd	nd
24	34	Oldenburg 2013	Traditional clinical versus simulation in 1st semester clinical students: students' perceptions after a 2nd semester clinical rotation.	1.277	USA	To analyze the immediate and long-term impact on students' perception of clinical competence after high-fidelity simulation.	Undergraduate (Baccalaureate)	95	1st	nd	nd
25	35	Powell-Laney 2012	The use of human patient simulators to enhance clinical decision-making of nursing students.	0.56	USA	To assess if HPS technology leads to greater clinical decision-making ability and clinical performance compared to the teaching modality of a paper and pencil case study.	Undergraduate (Licensed Practical Nursing)	133	na	32.0 (nd)	117 (88.0)
26	36	Rodgers 2009	The effect of high-fidelity simulation on educational outcomes in an advanced cardiovascular life support course.	1.615	USA	To determine subjects' educational outcomes through videos of subjects performing a simulated cardiac arrest after the conclusion of the course.	Undergraduate (Baccalaureate) Postgraduate (Associate)	34	4th na	32.5 (nd)	29 (86.5)
27	37	Roh 2014	Effects of high-fidelity patient simulation on nursing students' resuscitation-specific self-efficacy.	1.301	South Korea	To assess the difference in pre- and post-test self-efficacy after simulation training and to compare differences in between nursing students exposed to medium- or high-fidelity patient simulations.	Undergraduate (Baccalaureate)	163	2nd	IG 22.4 (5.9) CG 21.3 (4.0)	IG 25 (89.3) CG 125 (92.6)
28	38	Scherer 2007	A comparison of clinical simulation and case study presentation on nurse practitioner students' knowledge and confidence in managing a cardiac event.	1.04	USA	to compare the efficacy of controlled simulation mannequin (SM) assisted learning and case study presentation on knowledge and confidence of nurse practitioner (NP) students in managing a cardiac event	Postgraduate (Acute Care Nurse Practitioner, Adult Nurse Practitioner)	23	na	nd	nd
29	39	Shinnick 2014	Does Nursing Student Self-Efficacy Correlate with Knowledge When Using Human Patient Simulation?	1.277	USA	To demonstrate self-efficacy and knowledge gain in subjects who participated in high-fidelity simulation	Undergraduate (Baccalaureate)	161	4th	25.7 (nd)	142 (88.2)
30a 30b	40 41	Smith 2012	High-fidelity simulation and legal/ethical concepts: A transformational learning experience.	1.755	USA	To compare the new HFHS experience with in-person and online student groups using the same case	Undergraduate (Baccalaureate)	33 (a) 26 (b)	3rd	nd	nd
31	42	Tubaishat 2014	Effect of cardiac arrhythmia simulation on nursing students' knowledge acquisition and retention	1.313	Jordan	To evaluate the effect of simulation-based teaching on acquisition and retention of arrhythmia-related knowledge among nursing students	Undergraduate (Bachelor)	91	4th	20.4 (1.0)	56 (61.5)
32	43	Tuzer 2016	The effects of using high-fidelity simulators and standardized patients on the thorax, lung, and cardiac examination skills of undergraduate nursing students.	2.533	Turkey	To compare the effects of the use of a high-fidelity simulator and standardized patients on the knowledge and skills of students conducting thorax-lungs and cardiac examinations, and to explore the students' views and learning experiences	Undergraduate (Baccalaureate)	52	1st	23.0 (nd)	46 (88.5)
33	44	White 2013	Comparison of instructional methods: Cognitive skills and confidence levels.	1.277	USA	To compare the effectiveness of two instructional methods (traditional classroom method and high-fidelity simulator method) to teach content related to distributive shock.	Undergraduate (Baccalaureate)	54	nd	nd	IG 16 (100.0) CG 31 (82.0)

n = number of studies; k = number of estimates; IF = Impact Factor; N = sample size; Year = academic year attended;

Table C- Coding protocol for data extraction

Study (n), Scenario	Tool	Experimental	Control	N (IG /CG)	IG	CG	Statistical test	*p*
Objectively-evaluated Knowledge (n = 12, k = 13)								
[1] Cardiac arrest	14-item Multiple-choice [AHA, 2005c]	Laerdal SimMan®	No intervention	32/33	12.25 (1.22)	11.52 (1.15)	F test	0.015
[3] Cardiac arrest	12-item Multiple-choice [AHA, 2010]	METI™ version 6	Static half-torso manikin (Low-fidelity manikin)	52/58	9.10 (nd)	8.60 (nd)	Independent t-test	0.1
					t = 1.6			
[5] Cardiac arrest	14-item Multiple-choice [AHA, 2010]	METI™	Low-fidelity manikin	45/45	12.67 (1.06)	11.22 (0.90)	Independent t-test	≤0.001
[11] Preeclampsia	10-item Multiple-choice	HFPS	Laerdal vSim® (Medium-fidelity manikin)	42/42	4.80 (1.19)	4.12 (1.54)	Independent t-test	0.09
[12] Respiratory failure	12-item Multiple-choice	Laerdal SimMan®	Web-based learning	10/10	9.20 (1.30)	9.10 (1.70)	Independent t-test	0.891
[14a] Bronchiolitis	20-item Dichotomous	HFPS	Problem-based learning	62/69	0.86 (0.07)	0.83 (0.07)	nd	nd
[14b] Bronchiolitis	20-item Dichotomous	HFPS	Lecture	62/74	0.86 (0.07)	0.78 (0.11)	nd	nd
[19] Pulmonary edema	10-item Dichotomous	Laerdal SimMan®	Lecture	45/42	5.31 (1.29)	5.21 (1.47)	ANOVA	<0.001
[26] Cardiac arrest	ACLS Written Examination [AHA]	Laerdal SimMan®	Low-fidelity manikin	16/18	90.00 (7.59)	87.78 (9.05)	Mann-Whitney U test	0.447
[29] Heart failure, Pulmonary edema	12-item Multiple-choice HF Clinical Knowledge	Laerdal SimMan®	No intervention	89/72	61.39 (12.71)	55.47 (14.77)	Nd	nd
[31] Arrhythmia	20-item Multiple-choice [AHA, 2010]	METI™ version 6	Lecture	47/44	13.20 (3.35)	7.60 (2.36)	Independent t-test	≤0.001
[32] Intensive care	22-item Multiple-choice	HFPS	Standardized patient	26/26	72.79 (9.13)	73.80 (11.28)	Nd	nd
[33] Shock	10-item Multiple-choice Distributive Shock Questionnaire (DSQ)	HFPS	Lecture	16/38	6.75 (1.61)	7.82 (1.45)	ANOVA	<0.03
Objectively-evaluated Performance (n = 14, k = 21)								
[1] Cardiac arrest	BLS for Healthcare Provider Course Final Evaluation Skills Sheet for Adult CPR [AHA, 2001]	Laerdal SimMan®	No intervention	32/33	13.19 (0.78)	11.36 (1.27)	F test	0.000
[4a] Intensive care #1	Ad-hoc	Laerdal SimMan®	No intervention	49/50	47.54 (8.46)	48.82 (10.26)	nd	nd
[4b] Intensive care #2	Ad-hoc	Laerdal SimMan®	No intervention	49/50	61.71 (7.53)	56.00 (9.46)	nd	nd
[5] Cardiac arrest	AHA BLS for Healthcare Provider Course Final Evaluation Skills Sheet for Adult CPR [AHA, 2005c]	METI™	Low-fidelity manikin	45/45	13.13 (1.01)	11.58 (1.63)	Independent t-test	≤0.001
[7a] Cardiac arrest, Pulmonary embolism, COPD	7-item Likert-type	HFPS	No intervention	11/6	5.04 (0.48)	3.64 (1.22)	ANOVA	<0.05
[7b] Cardiac arrest, Pulmonary embolism, COPD	7-item Likert-type	HFPS	Video-watching	11/10	5.04 (0.48)	4.74 (0.88)	ANOVA	>0.05
[8] Cardiac arrest	20-item Acute Myocardial Infarction Questionnaire (AMIQ)	METI™	Lecture	54/53	15.58 (2.13)	14.17 (1.86)	Independent t-test	0.002
[9] Dysrhythmias	30-item Multiple-choice ECG SimTest [Morrison, 2006]	Laerdal SimMan®	Lecture	70/70	1008.00 (nd)	1070.00 (nd)	Independent t-test	0.143
[10a] Heart failure	7-item Likert-type	METI BabySIM®	Audio listening	21/21	3.41 (0.33)	3.71 (0.30)	nd	nd
[10b] Heart failure	7-item Likert-type	METI BabySIM®	No intervention	21/12	3.41 (0.33)	3.23 (0.35)	nd	nd
[10c] Pneumothorax	7-item Likert-type	METI PediaSIM®	Audio listening	21/21	3.39 (0.32)	3.50 (0.29)	nd	nd
[10d] Pneumothorax	7-item Likert-type	METI PediaSIM®	No intervention	21/12	3.39 (0.32)	3.60 (0.34)	Nd	nd
[13] Bronchiolitis, Dehydration, Respiratory distress	RN Nursing Care of Children Content Mastery Test [Assessment Technologies Institute, 2008]	Laerdal SimBaby™ METI PediaSim®	No intervention	55/16	65.33 (6.86)	67.46 (8.45)	Independent t-test	0.19
[16] Cardiac arrest	25-item Multiple-choice [AHA, 2006]	Laerdal SimMan®	Low-fidelity manikin	24/25	22 (92.00%)	23 (93.00%)	nd	nd
[20a] Respiratory distress	Dichotomous	Laerdal SimMan®	Problem-based learning	13/17	20.08 (1.93)	18.19 (2.55)	Independent t-test	0.034
[20b] Cardiac arrest	Dichotomous	Laerdal SimMan®	Problem-based learning	18/15	27.56 (2.15)	23.07 (2.69)	Independent t-test	0.00
[21a] Asthma exacerbation	47-item Dichotomous Respiratory Assessment Checklist	HFPS	Role-play	14/16	32.90 (4.20)	28.90 (4.50)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	32.90 (4.20)	27.40 (4.90)	nd	nd
[22] Intensive care	24-item Dichotomous	HFPS	Lecture	15/19	19.00 (3.20)	16.00 (3.70)	nd	nd
[25] Cardiac arrest	Nd	Laerdal SimMan®	Lecture	66/67	69.70 (12.20)	61.60 (13.70)	Independent t-test	<0.001
[26] Cardiac arrest	ACLS Mega Code Performance Score Sheet [AHA]	Laerdal SimMan®	Low-fidelity manikin	16/18	73.60 (17.70)	64.60 (15.60)	nd	nd
Self-rated Satisfaction with simulation (n = 10, k = 13)								

[6] Hypovolemic shock, Bradycardia, Pneumonia, Pulmonary edema	17-item Likert-type Satisfaction with Clinical Experience Simulation Scale (SCESS)	Laerdal Resusci Anne with iStan®	Laerdal Resusci Anne with VitalSim® (Medium-fidelity manikin)	49/36	89.37 (6.18)	84.88 (6.98)	nd	nd
[12] Respiratory failure	5-item Likert-type	Laerdal SimMan®	Web-based learning	10/10	24.6 (0.97)	19.3 (2.90)	Independent t-test	<0.0001
[14a] Bronchiolitis	18-item Likert-type Satisfaction with Simulation Experience Scale (SSE)	HFPS	Problem-based learning	62/69	4.17 (0.53)	4.67 (0.39)	nd	nd
[14b] Bronchiolitis	20-item Dichotomous	HFPS	Lecture	62/74	4.17 (0.53)	3.48 (0.62)	nd	nd
[15] Cardiac arrest	7-item Likert-type	Laerdal SimMan®	Laerdal VitalSim® (Medium-fidelity manikin)	45/44	4.58 (0.44)	4.50 (0.48)	nd	nd
[17] Hypervolemia, Pulmonary edema	18-item Likert-type Satisfaction with Simulation Experience Scale (SSE)	Laerdal SimMan®	MegaCode Kelly™ with VitalSim™ (Medium-fidelity manikin)	352/352	4.51 (0.37)	4.42 (0.42)	Independent t-test	0.546
[19] Pulmonary edema	9-item Likert-type [Otieno, 2007]	Laerdal SimMan®	Lecture	45/42	3.39 (0.42)	3.03 (0.36)	ANOVA	<0.001
[21a] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Role-play	14/16	40.86 (6.71)	46.38 (5.97)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	40.86 (6.71)	41.00 (12.20)	nd	nd
[23] Cardiac arrest	5-item Likert-type	HFPS	Lecture	165/176	153/12	156/20	nd	nd
[28] Cardiac arrest	6-item Likert-type Open-ended Evaluation Instrument	Med Sim–Eagle	Lecture	13/10	2.85 (0.39)	2.85 (0.42)	Independent t-test	0.784
[30a] Cardiac arrest	1-item Likert-type	HFPS	Lecture	16/17	4.50 (0.73)	4.20 (0.75)	nd	nd
[30b] Cardiac arrest	1-item Likert-type	HFPS	Web-based learning	16/10	4.50 (0.73)	3.60 (0.52)	nd	nd
Self-rated Self-confidence (n = 15, k = 18)								
[2a] Pneumonia	Ad-hoc	METI™	Lecture	35/34	4.05 (0.48)	3.86 (0.53)	ANCOVA	0.034
[2b] Increased intracranial pressure	Ad-hoc	METI™	Lecture	35/34	3.37 (0.41)	3.56 (0.34)	ANCOVA	0.093
[3] Cardiac arrest	17-item [Arnold, 2009]	METI™ version 6	Static half-torso manikin (Low-fidelity manikin)	52/58	Student t = 3.91		Independent t-test	0.001
[4c] Intensive care	Likert-type	Laerdal SimMan®	No intervention	49/50	3.40 (0.80)	3.50 (1.00)	Mann–Whitney	0.819
[6] Hypovolemic shock, Bradycardia, Pneumonia, Pulmonary edema	26-item Likert-type Gains Perceived with High-fidelity Simulation Scale (GPHSS) [Baptista, 2013]	Laerdal Resusci Anne with iStan®	Laerdal Resusci Anne with VitalSim® (Medium-fidelity manikin))	49/36	80.73 (7.03)	78.73 (4.76)	nd	nd
[8] Cardiac arrest	34-item Confidence Level (CL) [Madorin, 1999]	METI™	Lecture	54/53	106.29 19.71)	113.51 (17.87)	Independent t-test	0.09
[11] Preeclampsia	27-item Likert-type Nursing Anxiety and Self-Confidence with Clinical Decision-Making Scale (NASC-CDM)	HFPS	Laerdal vSim® (Medium-fidelity manikin)	42/42	115.25 21.95)	104.89 (17.52)	Independent t-test	0.059
[14a] Bronchiolitis	27-item Likert-type	HFPS	Problem-based learning	62/69	3.57 (0.33)	3.69 (0.30)	nd	nd
[14b] Bronchiolitis	20-item Dichotomous	HFPS	Lecture	62/74	3.57 (0.33)	3.38 (0.44)	nd	nd
[18] Cardiac arrest	70-item Likert-type Nursing core competencies measurement tool [Lee, 2011]	Laerdal SimMan®	No intervention	23/26	256.47 32.33)	247.26 (23.17)	Fisher's exact test	0.008
[19] Pulmonary edema	13-item Likert-type	Laerdal SimMan®	Lecture	45/42	4.06 (0.47)	3.82 (0.55)	ANOVA	0.011
[21a] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Role-play	14/16	3.50 (0.94)	4.31 (1.01)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	3.50 (0.94)	4.21 (0.70)	nd	nd
[22] Intensive care	33-item Likert-type Nursing Competencies Questionnaire [Bartlett, 1998]	HFPS	Lecture	15/19	84.40 (1.20)	81.21 (2.70)	Mann-Whitney U test	<0.01
[23] Cardiac arrest	5-item Likert-type	HFPS	Lecture	165/176	146/19 *	136/40 *	nd	nd
[24] Intensive care	5-item Likert-type	HFPS	No intervention	64/31	20.31 (2.13)	18.65 (2.65)	Independent t-test	<0.001
[29] Heart failure, Pulmonary edema	3-item Likert-type [Ravert, 2004]	Laerdal SimMan®	No intervention	89/72	2.47 (0.86)	2.08 (0.97)	nd	nd
[33] Shock	34-item Likert-type [Madorin, 1999]	HFPS	Lecture	16/38	111.38 16.27)	108.26 (14.55)	nd	>0.05
Self-rated Self-efficacy (n = 4, k = 5)								
[18] Cardiac arrest	28-question Likert-type Academic self-efficacy tool [Kim, 2001]	Laerdal SimMan®	No intervention	23/26	114.83 13.90)	110.19 (13.15)	Fisher's exact test	0.167
[21a] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Role-play	14/16	18.79 (4.17)	21.63 (3.30)	nd	nd
[21b] Asthma exacerbation	17-item Likert-type Health Assessment Educational Modality Evaluation (HAEME)	HFPS	Standardized patient	14/14	18.79 (4.17)	19.50 (3.01)	nd	nd

[22] Intensive care	Likert-type General Perceived Self-Efficacy Scale (GPSES) [Schwarzer, 1997]	HFPS	Lecture	15/19	148.0 (14.80)	149.0 (10.76)	nd	nd
[27] Cardiac arrest	Resuscitation Self-Efficacy Scale [Roh, 2012]	Laerdal SimMan®	Laerdal Resusci Anne® (Low-fidelity manikin)	28/135	3.82 (0.39)	3.45 (0.58)	Independent t-test	<0.001

*: no. of students with correct/incorrect outcome data.

Note: studies in the first column are labelled with the corresponding number exhibited in the previous 'Description of included studies'.

Table D - List of study design feature checking (studies with allocation to interventions at the individual level)

N / Items	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]	[29]	[30]	[31]	[32]	[33]
a1	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y
a2	Y	Y	Y	Y	Y	N	N	Y	N	N	N	Y	N	Y	Y	Y	Y	Y	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	Y
b1	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N	Y	N	Y	N	N
b2	Y	Y	Y	Y	Y	N	Y	N	Y	N	Y	Y	Y	N	Y	Y	Y	N	N	N	Y	N	Y	N	Y	N	N	Y	N	Y	N	Y	Y
b3	N	N	N	N	N	N	N	P	N	Y	N	N	N	P	N	N	N	P	P	Y	N	N	N	P	N	Y	P	N	N	N	N	N	N
b4	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
b5	N	N	N	N	N	N	N	P	N	N	N	N	N	P	N	N	N	P	P	P	N	N	N	P	N	P	P	N	N	N	N	N	N
b6	N	N	N	N	N	N	N	P	N	N	N	N	N	P	N	N	N	P	P	N	N	N	N	P	N	N	P	N	N	N	N	N	N
b7	N	N	N	N	N	N	N	P	N	N	N	N	N	P	N	N	N	P	P	N	N	N	N	P	N	N	P	N	N	N	N	N	N
b8	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
c1	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	P	Y	Y	Y	Y	Y	Y
c2	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	P	Y	Y	Y	Y	Y	Y
c3	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	P	Y	Y	Y	P	P	Y	Y	Y	Y	P	Y	Y	P	Y	Y	Y	Y	Y	Y
c4	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
d1	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
d2	P	P	P	P	P	P	P	Y	P	P	P	P	P	Y	P	P	P	Y	Y	P	Y	P	Y	Y	Y	P	Y	Y	P	Y	P	Y	Y
	Q-RCT	Q-RCT	Q-RCT	Q-RCT	Q-RCT	RCT	Q-RCT	CBA	Q-RCT	NRCT	Q-RCT	Q-RCT	Q-RCT	CBA	Q-RCT	Q-RCT	Q-RCT	CBA	CBA	NRCT	Q-RCT	RCT	Q-RCT	CBA	Q-RCT	NRCT	CBA	Q-RCT	RCT	Q-RCT	RCT	Q-RCT	Q-RCT

Notes: Was there a comparison: (a) [between two or more groups of participants receiving different interventions? (a1)], [within the same group of participants over time? (a2)]. Were participants allocated to groups by: (b) [concealed randomization? (b1)], [quasi-randomization? (b2)], [by other action of researchers? (b3)], [time differences? (b4)], [location differences? (b5)], [treatment decisions? (b6)], [participants' preferences? (b7)], [based on outcome? (b8)]. Which parts of the study were prospective? (c) [identification of participants? (c1)], [assessment of baseline and allocation to intervention? (c2)], [assessment of outcomes? (c3)], [generation of hypotheses? (c4)]. On what variables was comparability between groups assessed: (d) [potential confounders? (d1)], [baseline assessment of outcome variables? (d2)].
Y: yes; N: no; P: possible; RCT: randomized controlled trial; Q-RCT: quasi-RCT; NRCT: non-RCT; CBA: controlled before-after.
Note: studies in the first column are labeled with the corresponding number exhibited in the previous 'Description of included studies'.

Table E - Quality appraisal of included studies according to NICE checklist

Items / N	1.1	1.2	1.3	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	3.1	3.2	3.3	3.4	3.5	3.6	4.1	4.2	4.3	4.4	4.5	4.6	EV	IV
1	-	-	-	+	++	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	-	-	+	+	-	+
2	++	-	-	+	+	-	-	+	-	+	+	++	+	-	+	+	+	+	+	+	-	++	+	+	+	-	+
3	++	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	-	+
4	++	++	++	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
5	++	++	++	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
6	++	-	-	++	+	+	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	-	+
7	-	-	-	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	-	-	-	+	+	-	+
8	++	+	+	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	++	+	+	+	+	+
9	++	-	-	+	+	-	-	+	-	+	+	++	+	+	+	+	+	+	+	+	++	++	+	+	+	-	+
10	-	-	-	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	-	++	+	+	+	-	+
11	++	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	+	++	+	+	+	-	+
12	+	+	+	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	++	+	+	+	+	+
13	-	-	-	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	++	++	+	+	+	-	+
14	-	++	++	-	++	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
15	-	+	+	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	+	-	++	+	+	+	+	+
16	-	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	++	++	+	+	+	-	+
17	+	-	-	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
18	-	+	+	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	-	-	+	+	+	+
19	+	+	+	-	++	-	-	+	-	+	+	-	+	-	+	+	+	+	+	-	-	-	-	+	+	+	+
20	+	-	-	-	++	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	++	++	+	+	+	-	+
21	-	-	-	+	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	++	++	+	+	+	-	+
22	-	-	-	++	++	+	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
23	++	-	-	+	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
24	-	-	-	-	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
25	++	+	+	+	+	-	-	+	++	+	+	++	+	+	+	+	+	+	+	nr	++	++	+	+	+	++	+
26	++	-	-	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
27	++	++	++	-	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
28	-	+	+	+	++	-	-	+	na	+	+	++	+	-	+	+	+	+	+	+	++	++	+	+	+	+	+
29	++	++	++	++	+	+	-	+	++	+	+	++	+	-	+	+	+	+	+	+	++	-	-	+	+	++	+
30	-	-	-	+	++	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
31	++	+	+	+	+	+	-	+	++	+	+	++	+	-	+	+	+	+	+	+	-	-	-	+	+	++	+
32	++	-	-	++	+	-	-	+	++	+	+	-	+	-	+	+	+	+	+	nr	-	++	+	+	+	-	+
33	+	++	++	++	+	-	-	+	++	+	+	++	+	-	+	+	+	+	+	nr	++	-	-	+	+	++	+

na: not applicable; nr: not reported; EV: external validity; IV: internal validity.

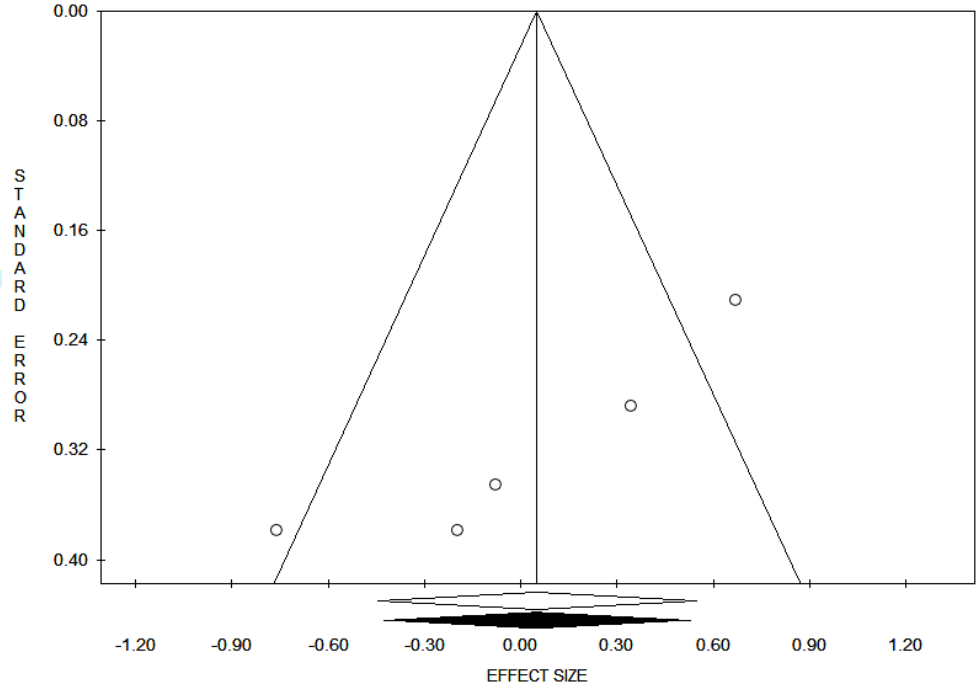

Figure 2 - Funnel plot for self-efficacy

PRISMA 2009 Checklist

PRISMA Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	1
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	1-2
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	2
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	2-3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	3
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	3; Box in Supplementary file
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	3
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	3
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	3
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	4; Table A in Supplementary file
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	4
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	4
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	4
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	4
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	4; Figure 1; Figure 1 and Table B in Supplementary file
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	5; Table C and D in Supplementary file
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	5-6; Table E in Supplementary file
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	6
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	6; Figures 2-6
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	7; Figure 2 in Supplementary file
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	6
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	7-8
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	8-9
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	9
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	9